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ARCHITECTS AND ENGINEERS.

From "The Builder."

The generalizing tendencies of the present day, the result mainly of the broader analysis of modern science, concur to draw together and assimilate, in many points, pursuits and professions formerly separated by an easily recognized line of demarcation. As we draw nearer in our researches to the first principles in science and art, we come almost insensibly to find things which we had been accustomed to regard as essentially diverse in their nature, resting, in fact, very much upon a common basis; we discover that knowledge and information which have been supposed to bear specially upon one particular occupation, come in usefully also, or even indispensably, in the practice of other pursuits more or less analogous. The primary effect of such discovery is, as we have hinted, to unsettle and confuse the nominal boundaries of professions, a process which is still more accelerated by the rapidity of modern life and the comparatively short time in which everything nowadays is expected and demanded to be done. "That is best which lieth nearest" is the principle adopted by the practical man as well as the artist. The client goes to whomever he thinks will supply him most readily and quickly with what he wants. But the secondary effect of this state of things must necessarily be in the end to narrow the circle of individual practice in any art or profession, to promote the principle of the division of labor, and to break up large and ever widening spheres of labor into smaller subdivisions, so that each practitioner may be able to grasp fully what he professes to do, and to render efficient aid and co-operation towards the grand result to be attained.

It is under such general influences as above indicated, that the two professions named at the head of this article have, at present, got themselves a good deal confounded together in the public mind; which confusion has been, if not initiated, at least encouraged and stimulated, by sundry members of the engineeering profession, individually or through their recognized journalistic representatives, on the principle, assumed if not stated, that "an architect and an engineer are very much alike — especially an engineer." The distinction between the two professions was formerly sufficiently recognized by every one, and might in broad terms be expressed thus: that the engineer was concerned in providing for transit from one place to another, the architect in erecting buildings *in situ* at the various termini of locomotion. The older engineers made their fame by their canals, their bridges, their roads over impossible places; the architects by their mansions, their town-halls, and public buildings generally. But the advent of that great democratizing agent, steam, for a time very much modified all this. In the first place, the discovery of so new and valua-

ble an agent in locomotion naturally drew everybody's attention, much more than formerly, to the constructions required in connection with locomotion, rather than to those needed for habitation or display. Railways became an end rather than a means, so that in some cases the natural order of things was reversed; and instead of the railway being used as a means of communication between two towns, unimportant towns were made the excuse for a railway, projected and surveyed, if not completed. In such a state of things the engineering profession of course got a long pull, and a strong pull, and a pull altogether, alike upon the purse and the confidence of the public; giving, let it be said, good and strenuous labor in return. Then there were, in connection with railways, such things as terminal and roadside stations to be built; things bearing the semblance of being strictly architectural work, but which, nevertheless, fell largely into the hands of the engineers, as many direful structures up and down the country can and do abundantly testify. Then also, since the time saved in travelling has led inevitably to our much faster rate of living generally, and the demand for the execution of edifices of all kinds on much shorter notice than was once deemed necessary, it has been discovered in some important instances that the engineer, from his constant grappling with tough constructional problems under adverse circumstances, is a readier man in an emergency than the architect; and so there has passed into his hands the superintendence of sundry erections, from time to time, which, if there be anything at all in the architectural profession, certainly ought not to have been built without, at least, the co-operation of an architectural designer. However, the mischief is done now; and that which has in some instances come to pass in practice, has been justified in theory, in certain quarters, with a persistence and an ability which have not been without their effect on the public, who will believe anything if they only hear it often enough, and many of whom are already quite prepared to accept the engineers' own account of themselves, as the persons best qualified to superintend the contriving of all such structures as might, could, or should be erected upon the surface of the earth. This view of the matter is partial and incorrect in itself, discouraging to the student of architecture, and exceedingly pernicious to the student of engineering.

Of course, as we all know, every design must have a structural basis, and therefore knowledge of construction is necessary to the architect, whatever he is engaged upon. It is only when the constructive necessities of a building, or of a structure of any kind, completely override in importance its artistic necessities, or when the constructive problem is so difficult and complicated as to be itself an object of special study, and of the application of abstruse scientific and mechanical principles, directed by a judgment resulting from long practical experience, that the aid of the engineer is really necessary. There are classes of works which belong purely and absolutely to the engineer, and wherein there can scarcely be said to be any scope for architectural embellishment; there are again works, such as ordinary houses, churches, etc., where the only problems really requiring thought and intellect are those of design (including plan) and ornamentation; and there are again works belonging by custom and in their initial form to the engineer, which would yet be susceptible of much embellishment from the hand of the architect; and, conversely, works of which the main object is beauty, but which are erected under structural conditions which demand special engineering skill and science to grapple with them successfully.

And this latter class of works, of what we may term the mixed kind, is much more numerous in the present day than ever it has been hitherto, and is not perhaps likely to become less so. It might seem natural and right that the mere channels of locomotion, of access from one centre to another, should fall solely under the hand of the engineer, as works purely of necessity and for use. And in the old road and canal-making days this was of course the case. But now that the railway system has necessitated so many stopping-places on the road, apart from ordinary towns and villages, where erections of great size are required for the daily use and under the daily sight of many thousands of people (not to speak also of the multitude of roadside stations, important by their number and frequency, if not by their size), it is surely desirable that some special attention should be paid to the

æsthetic beauty of such structures, in addition to their mere constructive strength and fitness. In some cases this has been done, but chiefly in the matter of small roadside stations; the large termini being still left, for the most part, under the sole care of persons whose very education tends to draw their minds completely from considerations of beauty and expressiveness in an edifice, and to develop their faculties on the practical and calculating side only. On the other hand, the demand for the production of very large buildings on very short notice, and sometimes under peculiarly difficult conditions, which has arisen under modern civilization, tends to put the architect in a very different position with regard to the practical requirements of his profession. A Gothic cathedral was a thing elaborated slowly and deliberately, and may have been the result less of any accurate scientific theories than of practical experience attained by men who were constantly engaged on their work, thinking of little else, and who had time to deliberate and to experiment. Now everything is wanted to be turned out of hand by a certain date, and its constructive security must be guaranteed, or the insurance companies will have nothing to say to it. And all this seems to lead us to what we have called the secondary, but inevitable result of the conditions of modern life, viz., the carrying out to a greater extent the principle of the division of labor, and restricting the practice of each profession within closer limits. In other words, we think that not so much a fusion of the professions of engineer and architect is called for, as a co-operation of the members of those professions each in his own strictly defined sphere.

It may be said that we should rather attempt to educate our engineers better in design, our architects more thoroughly in construction, and so dispense with the inconvenience of having two professions to do, as it sometimes seems, the same thing. Our system of education would have to be very much methodized and improved before any such result could be obtained. But we believe the idea is chimerical, except with regard to peculiarly gifted and exceptional individuals. Architectural design, in a high form, rests, as we have frequently urged, upon very subtle and refined principles, not apprehended without considerable study, even by those who have a special gift that way; and the very quality of mind which predisposes a man for this class of study is that which has most antipathy to, sometimes even absolute inability for, mathematical and mechanical studies. "Ah! sir," said William Blake, on being shown some mechanical engravings, "these things we artists *hate*." On the other hand, it cannot be doubted, not only that the highest engineering talent is very often found totally unaccompanied by what we may term æsthetic perception, but that, as bebefore remarked, the very course of an engineer's education tends to draw his mind solely to the consideration of the mechanical properties of material, without any reference to their capability for beauty of form or finish. And the very rapidity of demand in the present day intensifies the importance of this distinction. Were there more time allowed for maturing the design and carrying out the construction of a large building, there might be more chance that one man would be able to provide at once for its constructive and artistic requirements. As it is, except in cases where one of these two classes of requirements is at a minimum, it is next to impossible for one mind to attend properly to things so diverse, and calling into play such a different class of faculties. Where the constructive and the artistic problems are equally balanced, and are each important in themselves, a fully satisfactory result can scarcely be obtained but by co-operation.

We should probably not have much difficulty in recommending such an idea to the consideration, at least, of members of the architectural profession. In some instances within our knowledge, the calling in of an engineer as consulting constructor has been adopted by an architect, and that voluntarily. And there are probably many cases where, in carrying out very large works especially, an architect who was solicitous for his future fame as a designer, would be really glad to be relieved from the onus and responsibility of the thousand and one practical difficulties and dangers to be provided for or guarded against, and have his mind left free to bestow all its faculties on the great end of all architecture, rendering a building a delight instead of a nuisance. We are sorry that we can feel no such confidence, or half-confidence, in the converse

case. The attitude taken by the engineers towards their architectural brethren has too much savored of an antagonistic, or, at least, a kind of "we-can-do-without-you" feeling. When Professor Kerr, some years ago, in a paper read at the Institute, and printed in full in these columns, ventured to advocate something like the same system of co-operation which we have been hinting at, he was answered in an indignant and injured tone by an engigeer correspondent, who assured him that engineers "would not put themselves into architectural harness." No one ever asked them to do anything which ought to be so defined. Those who take this tone, no doubt, think that they evince their superiority by so doing; that they speak from a superior stand-point to that occupied by those half-taught people, the architects. They are quite mistaken. Their arrogance is that, not of knowledge, but of ignorance. But the mischief is, that, from the nature of the case, it is often impossible to convince them of this. Mathematical and mechanical knowledge is a thing that can be defined; and if an architect is deficient in this, his deficiency can easily be proved to him, though he is, of course, open to say, if he choose, that he thinks it of no consequence to him. But if a man is insensible to the difference between beauty and ugliness, between an artistic and expressive and an inartistic and meaningless structure, what can we say? He is insensible, and there is an end. You cannot demonstrate to him, logically, that he has erected a monstrosity upon the earth; for all that he can see, it looks all right, and he does not know what more you can wish for. The absurdity is, that with all this ignorance of and indifference to what constitutes the æsthetic in building, the engineers still seem to have a kind of lurking conception that something called architecture is needed to give the finishing touch to their constructions; and this they set about supplying by the light of nature; that is to say, instead of letting the real construction of their work appear, they mask it behind something which resembles something else which has been done somewhere else by somebody else at some other period, ancient or modern, and which has no conceivable relation to the matter in hand, and then complacently think they have done the architect's work in addition to their own. All that they have really done is to deprive their work of all the solid and satisfactory expression which it might have had as a piece of unadorned construction, and to make it, externally, a meaningless and often hideous sham. Pure constructive provisions, when made on a large scale, will often produce a fine general effect in spite of the engineer. We remember on one occasion being struck by a fine bold outline of a machicolated water-tower seen in the distance from the streets of a provincial town. The machicolations were used for the practical purpose of obtaining a wider area for the tank at the top. We took an opportunity of making a closer inspection of the edifice, and scarcely know how to express the effect it produced upon us. An attempt had been made at what might be called "lunar Gothic;" and every detail in the tower, and the surrounding buildings, was so uncouth, so inconceivably hideous and barbaric, that we stood lost in wonder how any man could possibly have invented such ugliness. Yet this was the work of an engineer eminent in his profession, and who, as we incidentally learnt afterwards, prided himself particularly on the appearance of this very building. He is dead now, and we trust his iniquities are forgiven.

The real remedy for this engineering intrusiveness of barbarism upon us lies with the public. And if the directors of railways and water companies, and such like concerns, could be got to insist upon the introduction of artistic as well as constructive excellence in the great works which their business requires, we might be spared some very painful sights, and even gain some very fine ones, with little or no extra expense. Consider what a fine thing might be made of such a large railway station as that of Crewe, for instance, with its long perspective, if treated with architectural breadth of effect in the general arrangement, and fitness and elegance in details. We see no reason why the engineer should feel insulted at such a proposition. We believe the architects are quite willing to recognize the importance of engineering experience and knowledge, and to avail themselves of it where really desirable. They may surely ask in return that their art should be recognized, and that engineers should be willing to consult the judgment of persons who have studied the art of beauty and expression

in building, which they themselves have paid no attention to. One piece of advice we give the engineers in the meantime: If they still wish to keep clear of the architects altogether, they had better be contented with naked construction, and avoid dabbling in architectural design themselves. They could do nothing which would illustrate more emphatically their need of the architect's assistance.

SURVEYING INSTRUMENTS.

By E. SHERMAN GOULD, C. E.

NO. III.—THE TRANSIT.

The most important points in the construction of the transit are the fitting and centring of the spindle, and the graduation of the limb and verniers. The graduating limb should be very fine and clear, and converging to the same centre on limb and verniers. The graduation of some instruments is so coarse as to render the precise reading of the vernier indeterminate. When it is remembered that the largest transits in general use have a limb of but 7 ins. in diameter, and that it is therefore from 2 points only 3½ ins. apart that lines are laid off, the necessity of fine work in the centring and graduation will be realized.

Both sides of both verniers should, in all positions, give respectively the same and corresponding readings, *approximately.* It is in the closeness of the approximation that the perfection of the instrument resides. The determining of the degree of approximation depends on the fineness of the graduating lines. The verniers of a coarsely graduated instrument will appear to agree more closely than they really do. If the verniers of a finely cut transit agree to within 10 seconds, it may be pronounced a good instrument. This variation would cause a divergence of about 3 ins. at the distance of 1 mile, between 2 lines of the same bearing turned respectively off the first and second verniers. The true line would be midway between these two erroneous ones. For any thing short of the highest order of work, this is a sufficiently close approximation.

The mere workmanship of a transit has a great deal to do with the accuracy of the operations performed with it. The telescope should "transit" smoothly and steadily, turning easily and yet remaining at any vertical angle without drooping. The different degrees of friction at different angles are often perceptible, and a telescope that stands at one angle will often droop at another. Nothing can be more annoying than this, which is also subversive of perfect accuracy, as the telescope must in such cases be steadied by the hand, which will alter the sight. The cross hairs should be exceedingly fine. The rack and pinion of the object-slide should work smoothly, and without play.

All the screws, etc., constituting the adjusting apparatus should work perfectly, or the surveyor will find great difficulty in adjusting his instrument with precision.

ADJUSTMENTS OF THE TRANSIT.

There are 3 adjustments of the transit which the surveyor can effect himself; they are very simple, but are apt to give considerable trouble to a person attempting them for the first time, on account of the delicacy of manipulation required. These are, *the adjustment of the levels; the adjustment of the line of collimation;* and *the adjustment of the horizontal axis of the telescope.* No matter how carefully an instrument may be handled, it is constantly liable to get out of adjustment, particularly as regards the line of collimation, and unless the adjustment be restored, grave errors will occur. It is therefore indispensable that the surveyor be able to adjust *perfectly* his transit, and familiarize himself with the tests by which any loss of accuracy may be detected. It is supposed that the surveyor is conversant, at least theoretically, with the *modus operandi* of effecting the adjustments; it will not therefore be described here. A good deal of practice is generally requisite to perfect the operator in the mechanical skill necessary to succeed in these manipulations.

The levels afford the means of testing the bearings of the spindle. Thus, after adjusting them on the rotation of the vernier plate, try them on the lower rotation. If the spindle runs truly, the bubbles will still retain their central positions.

The second adjustment, which consists in bringing the line of collimation at right angles to the horizontal' axis of the telescope, and the third adjustment, which consists in bringing the horizontal axis of the telescope at right angles to its vertical axis, depend upon each other. That is to say, neither can be performed with perfect accuracy until the other is effected. This difficulty can be parried, if in adjusting for collimation the ground chosen is perfectly level, and the back and fore sights placed exactly equidistant from the instrument. If these conditions are fulfilled, the line of collimation is rendered independent of the third adjustment. In practice, it is, of course, nearly impossible to secure a long stretch of perfectly level ground; the best that can be done is to get it as level as possible, making, if necessary, the sights quite short, and using small objects, such as shawl pins, instead of the chain pins usually employed when the sights are from two to four hundred feet. Another expedient, when ground sufficiently level cannot be procured, if the instrument is provided with a vertical limb, is to take the back and fore sights under the same measured angle of depression, irrespective of distance. It is best, when the third adjustment has been effected, to try the second over again, and reciprocally.

If the line of collimation gets disturbed in the field, and there are no facilities for rectifying it on the spot, set two hubs with the instrument, and place another one, by measurement, exactly between, for the true point. Even when the adjustment is as perfect as it can be made, it is best, in setting hubs at long distances, to verify by rotating the plate; and, in general, it is a good plan in ranging a tangent, to alternate the side of the transit turned forward.

It is assumed in the above adjustment that the tube of the object-glass is correctly centred. If it is not, the instrument must be sent to the maker for rectification. The state of the object-glass is easily ascertained by the line of collimation. If it is out of centre, the line can be adjusted while the glass is kept at the same focus, but if the focus is changed, the line will be found to be out of adjustment.

The final and crucial test of the adjustments is to try the line of collimation on objects at different levels and unequal distances, so as to necessitate a change of focus. If important work is on hand, the instrument should be thus tested before using it.

The limit of accuracy with which a straight line can be ranged with an instrument in perfect adjustment, is the degree of precision with which, in moving from station to station, the point bisected by the cross hairs can be indicated on the hub, the instrument plumbed over this point, and the point last left bisected in sighting back. There are so many causes operating in the field against perfect accuracy in the observations, such as high winds, rain, obstructed sights, the effect on the instrument of changes of temperature, incompetent flag-men, etc., etc., that this limit cannot be fixed. Perhaps it would be safe to say, that on a perfectly clear and still day, on favorable ground, and with thoroughly drilled assistants, the margin of error should not exceed a quarter to half an inch, according to the length of the sights, each time the instrument is moved. It may be doubted if, with the ordinary engineer's transit, of the best construction and in perfect adjustment, it is possible to reduce this limit. Any engineer who has had much regular field practice knows that it can very easily be overstepped.

It is a question, which must be decided according to the character of the work to be done, how far it is expedient to sacrifice time to great precision. The two desiderata of field operations are rapidity and accuracy. At the same time they are antagonistic. Some work demands strict accuracy. In such cases, time must not be taken into account. On the other hand, there are many cases where the surveyor will best serve the interests concerned by not pottering over the infinitesimals.

French Naval School.—We understand that the French Government is about to establish a great central school in Paris for the instruction of youths intended for the navy and mercantile marine. The education will not only include navigation and all connected with it, but the pupils will also receive a thorough commercial education, so as to render them fit for employment in any part of the world.

MANUFACTURE OF PILES, FAGOTS, OR BILLETS OF IRON OR STEEL.

From "The Practical Mechanic's Journal."

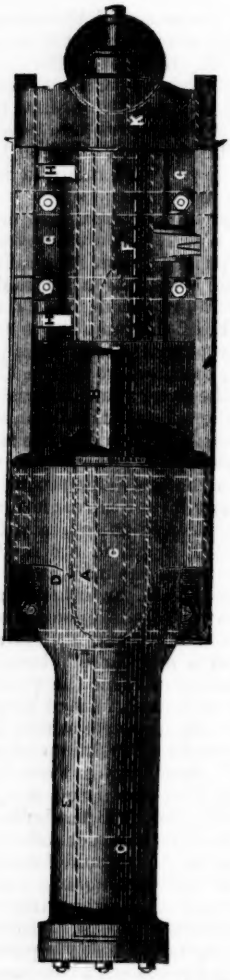
This invention relates to the making of piles, fagots, or billets of any desired shape, from which finished shapes or plain merchant irons or steels can be rolled; also to the making of hollow piles or fagots of iron or steel, from which pipes or columns can be rolled. The essential feature of the invention consists in the forming of iron or steel into piles, fagots, or billets preparatory to rolling, by pressing the metal into forms of the required shape; also in forming iron or steel into hollow piles or billets preparatory to rolling into hollow articles, such as pipes or columns. Various combinations or arrangements of machinery may be employed in manufacturing pressed and moulded piles or fagots as above described, but that which the inventor has found to give the best results up to this date consists of a hydraulic or other powerful press, the ram of which carries a plunger which accurately fits inside a strong metal case or mould of any desired size and transverse section, the sides of such mould being capable of opening on hinges in order to release the compressed and finished pile. The blooms having been placed in the mould, and the sides closed down and secured, the plunger is caused to enter through one end of the mould, which is left open for that purpose, and to forcibly compress by the action of the hydraulic press the metal contained inside the mould, thereby not only expelling the impurities which may be in the bloom, and which escape through the joints in the mould, but causing the metal to be thoroughly consolidated and to take the exact form of the mould. If a hollow pile, a punch or pointed mandrel of the required size and section is fitted into the end of the plunger, and on entering the mould perforates the bloom or blooms, and forces the metal laterally against the sides of the mould. The end of this punch passes through the opposite end of the mould, which has an opening in it just large enough to allow the punch to enter, and this opening is kept closed till the punch arrives by a sliding rod or stopper pressed forward by a counterweight. The punch having penetrated the metal in the mould, the plunger then enters and compresses the metal in a longitudinal direction, after which the plunger and punch are withdrawn. By reversing the action of the press the mould is opened and the finished pile, fagot, or billet, either solid or hollow, as the case may be, is removed in a state ready for rolling.

Fig. 1 of the accompanying engravings is a plan, and Fig. 2 a transverse section of this improved apparatus. A, Fig. 1, represents the piston of a hydraulic steam screw or lever press, which carries a plunger, B, of the same shape as the section of the pile required. This plunger B is hollow, to allow the piston C to move through the same; the said piston passes through the cylinder D into another cylinder E, lying behind and in the same plane as the cylinder D; the piston C is only used when hollow piles are to be made. The plunger B is of the same shape as the internal section of the opening formed by the dies F F F, which are held in place by the frame of the machine G G and by the hinges H H, or other contrivances which permit of the opening of the top form F, which, when open, allows the admission of a number of blooms of puddled iron direct from the puddling furnaces, or of blooms formed from puddled or other iron or steel which have been simultaneously brought up to a welding heat, and placed within these forms; the top being then closed and the power applied to the plunger B, the bulls or blooms will be forced into each other and into the shape of the mould formed by the closing of the dies against each other; the construction of these dies being such that they do not close so tightly as to prevent the expulsion of the impurities which may be in the blooms when placed within the dies.

When it is desired to form a hollow pile, the piston C has a pointed punch I, inserted in the end of the same, and the opposite end of the dies or forms has an opening left in the end, stopping up the forms corresponding to the size of the punch I, which opening is stopped up with a counterweighted stopper K. This stop-

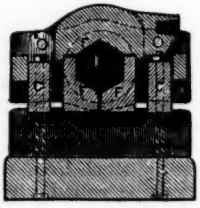
per is forced back when the punch, I, presses against it. The heated bloom being placed within the forms or dies, the pis-

FIG. 1.



ton, C, is moved forward, forcing the punch I through the metal, the rounded or pointed end of the punch causing the metal to be pressed aside rather than driven ahead; when this punch has passed through the metal and forced the stopper, K, back, the plunger, B, being of the shape of the opening form e l by the dies, is brought forward, thereby pressing the metal into the shape of the forms and solidifying it around the punch I.

FIG. 2.



When pressed up as far as required, the plunger or piston, C, is withdrawn by opening the escape valve and applying power to the other side of the points, thus withdrawing the punch from the metal. When this is accomplished, the pressure is removed from the plunger B, the dies are opened, and the pile is removed, which consists of a hollow homogeneous mass devoid of seam or opening, into which cinder, scale, or dirt can be forced in the process of reheating.

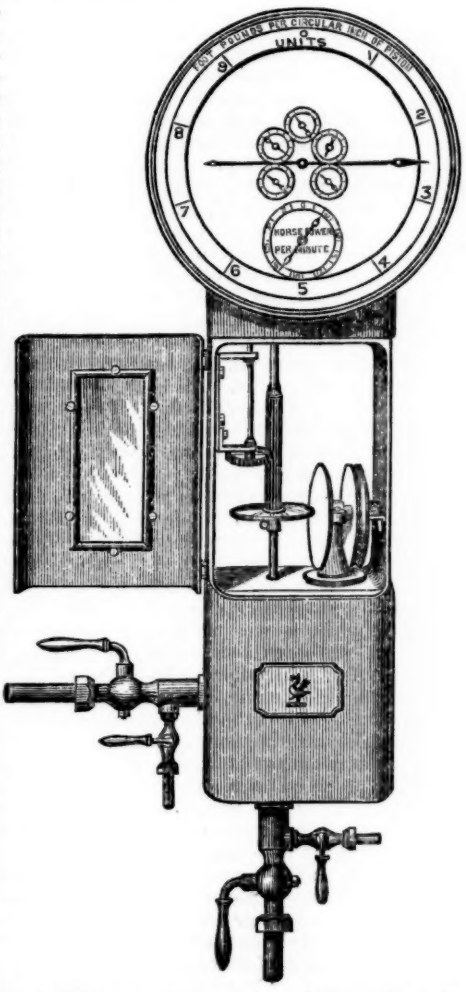
The power applied in either solid or hollow piles should be in proportion to the size and solidity required for the pile or billet. By the removal or insertion of the punch I, either solid or hollow piles may be formed in the same machine.

A WEEK'S WORK IN BIRMINGHAM in its aggregate results is something wonderful. It comprises the fabrication of 14,000,000 pens, 6,000 bedsteads, 7,000 guns, 300,000,000 cut nails, 100,000,000 buttons, 1,000 saddles, 5,000,000 copper or bronze coins, 20,000 pairs of spectacles, 6 tons of papier maché ware, £30,000 worth of jewelry, 4,000 miles of iron and steel wire, 10 tons of pins, 5 tons of hair-pins, hooks and eyes, and eyelets, 130,000 gross of wood screws, 500 tons of nuts, screw-bolts, spikes and rivets, 50 tons of wrought-iron hinges, 350 miles length of wax for vestas, 40 tons of refined metal, 40 tons of German silver, 1,000 dozens of fenders, 3,500 bellows, 1,000 roasting-jacks, 150 sewing-machines, 800 tons of brass and copper wares, besides an almost endless multitude of miscellaneous articles, of which no statistics can be given, but which, like those enumerated, find employment for hundreds and thousands of busy hands, and are destined to supply the manifold wants of humanity from China to Peru.—*The Engineer.*

CONTINUOUS INDICATOR.

By MESSRS. ASHTON AND STOREY.

This ingenious instrument was exhibited at the late Manchester Show. It is a steam power meter and continuous indicator, its use being to determine the amount of work done by an engine in any given time. Our engraving shows an elevation of the apparatus. In the lower part is placed a piston and a cylinder, working just as an ordinary indicator. The piston rod actuates a disc wheel, which slides against the face of a vertical rotating disc; both of these are shown in the cut. The horizontal disc actuates a train of mechanism, by which a hand is moved over a dial. When the indicator has no pressure on it, the horizontal wheel, being opposite the centre of the vertical disc, has no motion imparted to it; but the moment the piston rises under the influence of pressure, or falls under that of vacuum, the horizontal wheel has motion imparted to it, and it will move the further in a given time the greater the distance it is removed from the centre of the vertical disc; but this distance is determind by the pressure in the cylinder. The band actuated by the horizontal wheel records foot-pounds per minute, per hour, etc.; and, consequently, the greater the pressure in the cylinder the greater will be the travel of the horizontal disc, and the larger the number of revolutions made in a given time, and the larger the number of foot-pounds registered. The machine shows almost at a glance the power developed during each day or each hour, while dingrams can be taken, as with the ordinary indicator.—*Engineer.*



Within a few years £4,000,000 have been expended by the corporation of the city of London for city improvements.

The scientific departments at the Royal Arsenal have under investigation the merits of a 37-barrelled rifle said to be an improvement upon Montigny's mitrailleuse, which has been already adopted to some extent by the French Government. This consists of 37 rifle barrels bound together by hoops, the charges for the whole being contained in a movable breech-piece, and the barrels can be discharged singly or together by a turn of the hand. The "machine" has been found to make a good diagram at the targets, almost too good if it is intended to supersede grape shot. The rifling and the bullets are Metfords's and the charge 15 grains.

THE SAINT LOUIS BRIDGE.

From "Engineering."

The construction of the noble bridge, designed by Mr. James B. Eads to cross the Mississippi, and which we have already fully described and illustrated, is proceeding rapidly. Considerable progress has been made with the abutments and piers, and a large amount of preliminary work, and plant is upon the ground. There will be about 20,800 cubic yds. of masonry in each pier, one of which will be 97 ft. in height when completed to 10 ft. above low-water mark, and the other 69 ft., when finished to the same level. In sinking them, 78 ft. and 50 ft. of sand respectively will be passed through. The base of each pier is 82 ft. long, and the eastern is 60 ft., the western 48 ft. wide. At 10 ft. above low-water level, they are 78 ft. in length by 38 ft. wide. These piers will be sunk in caissons, one of which is nearly finished, and the other far advanced; nearly all the necessary machinery for this part of the work is completed, and much of it is in place upon the boats employed for the work. The machinery destined for laying the stone-work is of a novel character, and consists of a scaffolding about 50 ft. high, which supports 6 wire cables $2\frac{1}{4}$ ins. in diameter. On each boat and upon each cable is placed a traveller for hoisting and transporting the stone. Each traveller can move an 11-ton stone to a distance of 100 ft. They will be worked by hydraulic rams when raising and lowering the stone, and are provided with ordinary gearing for transporting it. Seven sand pumps will be used in the caisson of the eastern pier, and five in the western one, for removing the sand in the descent of the caisson. These pumps are of novel and ingenious construction, and their efficiency has been thoroughly tested, one of them having been used in 40 ft. of water, and found capable of discharging 10 cubic feet of water per hour. The principle is an adaptation of the Giffard injector, water being used instead of steam. A stream of water is forced at a high velocity down through a pipe, and discharged near the same into another pipe in an annular jet, and in an upward direction. The flow of the jet produces a vacuum below it, by which the sand is drawn into another pipe, the lower end of which is in the sand, and the force of the jet drives the sand upwards to the surface of the river as soon as it passes through the annular opening in the jet. The action of this pump is found to be certain, and it will pass gravel as freely as sand, the size of the stones which are discharged being of course regulated by the diameter of the opening. In the pump experimented on, the end of the discharge pipe was inserted to a depth of 19 ft. into the sand, the height of water over the top of the sand being 40 ft. Under these circumstances the action was unfailing, and the vacuum obtained was almost perfect. The pipes used in the pumps will be of 5 in. diameter, and about 2500 ft. will be required. By this arrangement one of the most important difficulties which presented itself with reference to the foundations has been avoided, and the inconveniences and delays attendant upon the use of dredging machines removed. The pumps will be placed on the top of the air chambers of the caissons, the suction pipes extending through the chambers into the sand, telescopic joints on the lower ends allowing the lengths to be extended more or less into the sand as required.

A large portion of the caissons is being made from the wreck of the United States gunboat *Milwaukee*, which was purchased for the Bridge Company, and the plates of her hull cut up for the purpose. The air chambers of both caissons are 9 ft. high, and the sides are formed of $\frac{3}{4}$ in. plate for the larger, and $\frac{5}{8}$ in. for the smaller one. The former is provided with seven air chambers, the latter with five. The area of the chambers is equal to that of the underside of the pier, and the roof has to support the whole weight of the column of masonry from its foundations to above the water level, a height of nearly 100 ft. The roof of the chambers carrying this mass is made of plates $\frac{1}{2}$ in. thick, stiffened above by 13 girders, placed 5 ft. 6 ins. apart. Each girder is 5 ft. deep, and is made of $\frac{1}{2}$ in. plates, with top and bottom chords. The space betwen these will be filled with masonry, and beneath the roof two wooden girders, running in an opposite direction to the iron ones, divide the area of each chamber into three equal parts. Openings in these girders give

communication from one part of the chamber to the other. They are intended to rest upon the sand, and so help to support the mass of masonry above, and relieve the roof of the chamber of a portion of its load. The sides of the chambers are of plate iron, strongly braced to resist the external pressure, and they are, therefore, stiffened with plate-iron brackets. Between the brackets, near the bottom, is placed all round the chamber a timber sill, the underside of which is on the same level as the bottom of the timber girders, and these will also rest upon the sand. A large amount of bearing surface is thus obtained, equal to about 850 sq. ft. This support, the friction of the sand outside the chamber, and the buoyancy of the compressed air within, will together sustain the pier in its gradual descent. In sinking the caisson it will be kept in place by means of 14 large guide piles 3 ft. 6 ins. in diameter, and which carry 10 screws each 25 ft. in length, which will regulate the descent, and secure a perfect equality of motion. The bottom edges of the chamber extend 2 ft. below the underside of the timber sills and guides, and form a cutting edge which will facilitate the sinking, and at the same time prevent any tendency to lateral movement. Before being floated into position, the sides will be extended to a height of 10 ft. above the top of the roof; and as the pier descends, the sides will be heightened.

Up to the first of September last $831,600 had been expended on the work, which now gives employment to about 1500 men. Under the active superintendence of Mr. J. B. Eads, who has recently been enabled to return to St. Louis and again take the undivided responsibility, it is probable that the bridge will advance still more rapidly toward completion.

ON THE MANUFACTURE OF PIPES.

From "The Mechanic's Magazine."

A much greater amount of importance attaches to the material of which pipes for the conveyance of water and other liquids for domestic purposes are made than people generally imagine or admit. The pipes conducting the water-supply from the mains into our houses are for the most part of lead, and this, of all others, is about the most dangerous material that can be used. Lead-poisoning is now so well known to result from the action of certain waters on the pipes that we need not stay here to insist upon the point. We will merely mention, in passing, that the fact that water is poisoned by being brought in contact with lead, has been known for several thousand years. Vitruvius, who flourished B.C. 46, forbade its use for this reason; whilst Galen, A.D. 130, condemned lead pipe for conducting water because of its injurious effects. We therefore proceed first to notice the various materials of which pipes are made, then to point out their respective defects or demerits, and finally to determine the material which should properly be employed for the purpose. Pipes, in general, are made of wood, iron, lead, copper, tin, stone, and pottery ware. To these substances we may add bitumenized paper, which has recently been introduced as a material for the manufacture of pipes, although we have had samples of this ware by us for nearly twenty years. Wooden pipes are the most economical in first cost, but their many drawbacks have long since led to their disuse, except, perhaps, in some very exceptional cases. They are wanting in strength to resist the pressure of fluids, and are liable to decomposition, decay, leakage, and infection by insects. Water, too, lying long in wooden pipes, becomes putrid from the animal and vegetable matter collected in them. Iron pipes are employed as street mains for conducting water, and sometimes for house purposes, but are troublesome from rust, difficult of repairing, and are liable to break at the joints when a settlement takes place in the surrounding soil.

The process of galvanizing iron pipes has met with considerable favor; but, in the main, we think it will be found to injure the tenacity of the iron, rendering it liable to split under pressure or during frost. It has, moreover, been found to corrode rapidly. At page 59 of "The Mechanic's Magazine" for July 28, 1865, we wrote as follows:—"The question of the best and safest material for the con-

struction of water tanks for ships is being discussed in France. Galvanized iron, it seems, has been employed in the French Navy, but this is condemned by M. Roux, the author of a memoir on the subject, who finds zinc in the water kept in such tanks, and in such quantities that he considers the liquid unfit for domestic use. He recommends for the Imperial Navy water tanks tinned inside." As already observed, lead pipe is commonly used for conducting water from the iron main pipes under the streets into and through buildings. The physical qualities of this pipe admirably adapt it for such use; and in this regard nothing better could be desired. It is easily bent, soldered, and repaired when damaged. These properties have influenced its adoption, notwithstanding a risk, popularly understood and admitted, of injurious results to the health of those employing it. With regard to copper pipes, we need only observe that they are rarely employed except in sugar refineries, breweries, and a few other exceptional cases. Tin pipe is employed for beer, soda-water, condensing worms of stills in the chemist's and pharmaceutist's laboratories, and occasionally for service pipe in dwelling-houses. Stone pipes have been used, and are perfectly safe and wholesome, but difficult to manufacture, and therefore too expensive for use. Pottery ware pipes can only be made in short lengths, are very liable to be broken, and cannot be made to stand a great pressure. It appears, from some ancient buildings, that the Romans sometimes made use of them.

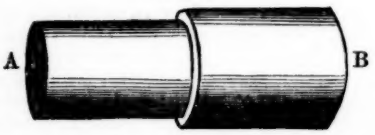
During the past fifty years inventors and manufacturers have bestowed much time and labor upon experiments for making a pipe which would possess the physical qualities of lead, and, at the same time, the chemical properties of tin. These experiments have been induced and stimulated by the advice of chemists and physicians respecting the want of such a pipe, as a substitute for, and to avoid the deleterious effects resulting from the use of, lead pipe. When eminent scientific and professional ability, devoted to the investigation of this subject, testifies to the existence of this evil and to the importance of its correction, it is absurd for individuals to interpose contrary opinions, entirely arbitrary, and based neither upon facts nor intelligence. These opinions are rendered still more absurd in many cases by the efforts they themselves have long been making to accomplish the same object. Among the various plans proposed, one consisted in tinning the ordinary lead pipe inside and outside by drawing it through a bath of molten tin. Another attempt was made to tin lead pipe on the inside by passing it over a hollow mandrel, through which the melted tin was supplied. The method usually employed at present to coat lead pipe is by passing the pipe, as it is formed, through melted tin held around the pipe above the die for the exterior coating, and supplying it for the interior from a perforated cup in the top of the core or mandrel.

This process forms a thin wash of tin which affords no protection against the lead, as an exposure to the atmosphere destroys in a few weeks all appearance of it, and the friction of water passing through the pipe removes it almost immediately. The process, when applied with the utmost care, is also extremely uncertain in the continuity of its action, often leaving spaces entirely untouched by the tin, and sometimes stopping up the pipe completely by the rapid cooling of the tin held in the cup, which then passes off in a lump, a circumstance not unfrequently discovered only when the water or gas is turned on, and thereby incurring the necessity of taking down the ceiling to remedy the fault. The cost of this pipe is from three to six shillings per cwt. more than the common lead pipe, while it possesses no advantage over it. Lead pipe has also been electro-plated with tin, but this was really no improvement upon the methods previously named. Several other plans have been tried, and more or less practised; but, while some have been attended with such difficulties in the manufacture as to make the pipe expensive, all have been imperfect up to the present time.

Now, however, we appear to have a remedy for the evil complained of in Haines' patent lead-encased block-tin pipe, which is being introduced by the manufacturers, Messrs. Walker, Campbell, and Co., of Liverpool. The pipe manufactured by these improvements differs in many respects from any other of its kind. The encased tin tube is made of any thickness desired, perfectly uniform throughout the whole of the pipe, and in coils of any requir-

ed length. The two pipes are made simultaneously, and the metals are so thoroughly united at their surfaces of contact that the junction cannot be disturbed, except by the application of heat sufficient to fuse them. In this peculiarity the pipe comports itself as a homogeneous metal, and yet the two metals composing it remain quite distinct in their mechanical and chemical properties. It has all the pliability and other qualities required by plumbers, which, with its great value as a sanitary agent, warrants the recommendation of it for general use. The accompanying figures afford an idea of the character of this pipe. They show the exact thickness and proportions. Fig. 1 represents a

FIG. 1,



specimen of lead-encased block-tin pipe, with a portion of the lead or outer pipe, B, removed, so as to show the tin or inside pipe, A.

FIG. 2

FIG. 3.

Figs. 2, 3, 4, and 5 are sections of lead-encased block-tin pipe and lead pipe, tested by hydraulic pressure, and highly spoken of in a report from Mr. A. W. Craven, Chief Engineer of the Croton Aqueduct Depart-

FIG. 4.

ment, in the United States. Experiments relating to the strength of these pipes have been repeatedly made, and comprise tests of all sizes in ordinary use. The pipes were subjected by hydraulic pressure to a bursting strain illustrating their comparative strength.

The section shown in Fig. 2 burst at 1,650 lbs. pressure sq. in., and that in Fig. 3 burst at 1,200 lbs. pressure sq. in.

The section shown in Fig. 4 burst at 1,325 lbs. pressure sq. in., whilst that shown

FIG. 5.

in Fig. 5 burst at 1,150 lbs. pressure sq. in. The heavy black line on the inside of Figs. 2 and 4 represents the tin as enclosed by the lead. From a number of testimonials we have perused, it appears that for conducting gas in public and private buildings this pipe is found to be a most admirable substitute for the heavier lead pipe, or the iron tube, which is so liable to corrosion. The interior surface is highly polished, and entirely free from flaws or inequalities, and thus, presenting no impediment to the flow of water or gas, affords no facility for the accumulation of deposits or tendency to oxidation, which is so frequently the cause of inconvenience or expense in the pipe ordinarily employed for this purpose. With regard to the all-important question of cost, as far as we have been able to ascertain, there is no difference in price between the new tubing and the ordinary lead pipe. It therefore appears a most desirable article, and its superiority in respect of immunity from poisoning leaves no doubt but that it will rapidly come into general favor. It only requires that the public should be made fully aware of the value of the encased tin pipe to insure that, for domestic purposes at least, none other should be used.

THE car shops of the Lake Shore Railroad at Buffalo were lately destroyed by fire. Loss, $300,000.

HEAVY ARTILLERY.

MR. LYNALL THOMAS ON ITS CONSTRUCTION.

From "The Engineer."

A careful student of the recent history of heavy artillery can hardly fail to remark that within the last few years no important innovations in their construction have been introduced. Mr. Fraser appears to have solved much further back the great problem which so long vexed the souls of artillerists, as completely as it can be solved with existing materials of construction. His guns are cheaper than any other guns even approaching them in power; and as regards endurance, it has been demonstrated over and over again, by direct experiment, that no weapons at once so reliable and so terrible have ever been manufactured either for mere experiment or for actual warfare. England possesses the best heavy guns in the world, and of this fact she may be, and as a nation is, proud; but those who have much would have more, and English artillerists still wish for guns which, possessing the same powers of penetrating or smashing structures, whether ships' sides or armored forts, will also possess qualities of greater endurance than any gun yet made is likely to exhibit. We are not content with guns which will fire 300 charges of 70 lbs. of the strongest powder in the world, with shot or shell of proportionate weight. We want guns which will do this and a good deal more; we want guns which will fire at least 1,000 such charges, and such guns in large numbers we do not possess. Government artillerists cannot stand still, yet they are in a cleft stick. To improve on Mr. Fraser is apparently impossible, for the simple reason that Mr. Fraser has, in a sense, got all out of iron and steel that they can give. So artillerists, abandoning the improvement of the gun, have turned their attention to the powder which burned inside it, and we already hear rumors of the commencement of an elaborate and exhaustive inquiry into the composition and form which powder intended for heavy guns should possess. As we cannot strengthen our guns, it is proposed that our powder should be made weaker; and it is by no means impossible that as many millions may be spent on the new investigation as were wasted on the breech-loading scheme introduced by Sir William Armstrong. Such a result would be in every way deplorable, and it is worth while to call attention to some of the facts of the case, Powder *v.* Guns; to examine what has already been done; and to suggest certain points, due attention to which may save public money by directing experiment into proper channels.

On all points connected with the strength of gunpowder, and its action on a gun, the opinions of no artillerists are entitled to very much more consideration than are those of Mr. Lynall Thomas. No private gentleman, we believe, has spent so much money or so much time in experimenting on the phenomena ensuing on the combustion of large and small charges of powder, and we, therefore, welcome the publication of a pamphlet which contains all the results of his experience embodied in an expression of opinions based on these results. Mr. Thomas claims to have been the first to demonstrate the great truth that, as the quantity of powder burned in any gun increases, the strain on the gun augments in an enormously greater proportion than the weight of the powder charge; and from this he deduces certain rules for the construction of guns, which, curiously enough, although ignored by artillerists in theory, apparently regulate the best practice of the day. Indeed, readers of Mr. Thomas's works can scarcely fail to recognize the remarkable correspondence which exists between the laws of construction he has laid down, and the proportions of the strongest existing guns adopted in practice. In order to render Mr. Thomas's views clear, it will be necessary to go back a little way in the history of artillery, and cite a treatise on rifle ordnance published by Mr. Thomas about six years ago. This work contains the reprint of a very able and original paper "On the Nature of the Action of Fired Gunpowder," read before the Royal Society, in December, 1868; and in it Mr. Thomas lays down the important law that the action of a charge in a cannon may be considered of a compound character, consisting, firstly, of an impulse which causes the ball to begin to move with a finite velocity; and, secondly, of the pres-

sure of the fluid generated from the powder. This pressure will be continually augmented by the generation of fresh elastic fluid as the more perfect combustion of the powder takes place, until the whole is completely consumed up to a certain quantity peculiar to the bore of the gun and the quality of the powder used. The whole of the charge may be ignited before the shot is moved, although perfect combustion may not take place.

"The essential point to be considered in the construction of a gun is the general effect produced on the gun by different charges of powder." Mr. Thomas opens his last contribution to the science of artillery with these words, and no one will dispute their truth. He then goes on to show that the accepted theory of the action of powder in guns is contrary to the views he expressed in 1858, and continually compares the action of fired gunpowder to that of a pressure of an elastic fluid within the bore, totally neglecting the percussive action which takes place at the moment of first ignition, which is really the element of destruction as far as the gun is concerned. It follows as a natural consequence, that the strain produced on a gun by the combustion of any given weight of powder, is regarded as simply increasing in the direct ratio of the weight of the charge; and numerous attempts have been made to estimate the force, or, more properly speaking, the pressure exerted within the bore of a gun when a charge was fired. It was assumed that the pressure was identical in a little swivel firing half a pound of powder and a 68 cwt. gun firing ten or twelve pounds, a proper allowance, of course, being made for the difference in the surface acted on by the gases resulting from the combustion of the powder; and, thanks to this theory, all guns were increased in thickness, not in proportion to the weight of the charge, but in relation to the calibre. Thus, the old service 9 lbs. gun, with a bore of 4.2 in., was as nearly as possible half the size in every way except length, of the old 68 lbs. 8 in. gun; and the thickness of metal in the walls of the 68 lbs. gun, measured at a point just in advance of the shot, is as nearly as possible double that of the walls of the 9 lbs. gun. In the former the bore is 8.12 in. in diameter, and the metal about 10 in. thick; in the latter the bore is 4.2 in. and the metal about 5 in. No one appeared to see anything wrong in this, although practice proved that it was wrong, because the charges of powder by no means increased in the ratio of the calibres, and the proof charges of the big guns were very much smaller in proportion than those of the small cannon. Mr. Lynall Thomas showed by an exhaustive series of experiment, that the thickness should augment in a very rapid ratio as compared with the bore, and in modern guns we find that, although his rules, and the experiments from which they were deduced, have been passed over with the silence of neglect, the first have been practically adopted, the thickness of the walls of the modern 9 in. gun being not less than 15.35 in. instead of being about 11.7. It must not be supposed that Mr. Thomas overlooks the fact that increasing the thickness of a gun does not in one sense add to its strength beyond a certain limit. But he holds, and very properly, that mass of metal is absolutely necessary in big guns, not to withstand the mere pressure of the gases, but to take up the percussive shock caused by the initial action of the fired charge, just for the same reason that weight—mere dead weight—is required in the anvil block of a steam hammer.

In further elucidation of these views, we cannot do better than let Mr. Thomas speak for himself. "In the first place (he writes) it must be observed that whilst the shot is traversing the initial space, the rest of the charge is undergoing complete conversion into gas; and when such conversion has taken place, the gas rushes forth in the direction of the axis of the bore. A considerable portion of this gas is driven into, or, more properly, condensed in that space that has just been vacated by the shot; and at this important instant the gun is called upon to sustain the greatest possible strain that is exerted upon it. If the gun be of sufficient strength and thickness to endure the disruptive power of the charge, the chief effect of the intense pressure will be directed towards the removal of the shot. From the above explanation it will be seen that, in order to be able to calculate the different degrees of tension for different guns, we must first endeavor to investigate the mathematical relation subsisting between the initial velocity, the weight of the shot and of the charge, and

the diameter of the bore. As soon as we have determined in what manner the velocity depends upon these known quantities, we shall be able to express in terms of them the volumes into which the gas is condensed; and then it will be seen that the relative strains exerted upon different pieces can by an easy process of mathematical reasoning be expressed as algebraical fractions of certain known quantities."

Mr. Thomas then goes on to quote the results of several experiments more particularly referred to in his paper read in 1858. From these he deduces the four following laws:

(1.) When shot of the same weight and size were subjected to the action of different quantities of powder, fired in chambers of the same diameter, the initial velocities communicated to them were directly as the square roots of the weights of the charges employed. (2.) When shot of different weights were placed upon the same chamber, filled with the same quantity of powder, the initial velocities were inversely as the square roots of the weights of the shot. (3.) When shot of different weights were subjected to the action of different charges of powder, fired in chambers of different depth, but of the same diameter, the initial velocities were directly as the square root of the weight of the powder, and inversely as the square root of the weight of the shot. (4.) *When the diameter of the chamber was increased, the initial velocity was increased (with proportional charges) in the ratio of the square root of the diameter.*

The last of the foregoing is the most important of all, and we believe we only give credit where it is due when we state that it originated solely with Mr. Thomas. The general deductions from the laws we have quoted he formularizes thus:

"The initial velocity is given by $\sqrt{\frac{W'd}{W}}$, the tension or the bursting effect by $\sqrt{\frac{W\,W'}{d^3}}$, and the corroding effect of the pressure by $\sqrt{\frac{LL'}{d}}$.

The charges being supposed to be fired under the same conditions in each gun."

In these formulæ, W is the weight of the shot, W′ the weight of the powder, d the diameter of the bore, L the length of the shot, and L′ the length of the cartridge.

The practical effect of the discovery of the great increase in the force of powder, due to the augmentation in the quantity fired at one time, was sufficiently remarkable. In the days of the 68 lbs. smooth bore, the charge of the 9 lbs. gun was 3 lbs. of powder, which did not greatly tax the gun, while the charge of the 68 lbs. was 16 lbs. only, which taxed it severely. Yet, if the charges had been augmented in the proper ratio to the calibre, the 68 lbs. gun should have burned 24 lbs. of powder; but this it could not do, because it had not metal enough in it. Artillerists did not assign any reason, however, why it could not fire 24 lbs. charges with safety, except the absurd theory that as the size of the casting increased, its absolute strength diminished. Mr. Thomas, as we have seen, proved that the true cause of the apparent weakness of the big gun lay, not in the metal, but in the fact that the big charge exerted a much greater strain on the gun, pound for pound, than the small charge. The true remedy lay in increasing the thickness of the gun, not in the ratio of the augmented calibre, but in that of the force of the powder; and at a very heavy cost to himself, Mr. Thomas produced and tried a steel 7 in. gun, which fired a larger charge (24 lbs.) than had ever before been attempted in a gun of this bore. This gun burst because of a flaw, but not till it had proved how great a stride could be made in the construction of artillery by attention to proper principles.

It is obvious from what we have said, that we hold that the strain exerted on the interior of a gun augments in a very rapid ratio with each increase in the weight of powder fired. That Mr. Thomas practically put this theory forward years ago, no one can dispute; yet we find Sir Wm. Armstrong speaking of the theory as a new discovery, in his opening address, delivered the other day at Newcastle, without the slightest allusion to Mr. Thomas's labors; which is, to say the least, scarcely fair to the last-named gentleman. This is a matter, however, which concerns only Mr. Thomas and Sir William Armstrong. The carrying out of a costly series of experiments on the strength of powder, and the influence exerted by quantity on strain, is a very different matter. It is possible that Mr. Thomas has very nearly, if not quite, done all in this direction that need be done; and it will not be a little vexatious if, at the end of 5 or 6 years, and after the expenditure of enormous sums of money, we find ourselves just in the position in which Mr. Thomas has placed us now. That the best modern guns are unwittingly constructed in accordance

with this theory, and are successful because they are so constructed, he maintains by very weighty arguments. Other claimants to the honor of Mr. Thomas's discovery will possibly start up the moment its value is proved, but with this the nation has really very little to do; truth will, no doubt, prevail, and the honor will rest in the end with the right man. What the nation has to consider is, first, not whether Mr. Thomas's views are original with him or not, but whether they are true; secondly, whether the proposed inquiry into the action of gunpowder will confirm or upset Mr. Thomas's theories; and, thirdly, whether it is worth while to expend a very large sum of money in settling the latter question. It would be as well, we think, that before any considerable expenditure is incurred, Mr. Thomas's theory should undergo a quiet and dispassionate examination at the hands of competent men, with a view to determine how far it is consistent, not only with reason, but with very well known facts in gunnery.

THE GEOLOGICAL RELATIONS OF IRON.

From "The Iron and Coal Trades Review."

[The following paper was read on Monday evening, before the Science Section of the Cleveland Literary and Philosophical Society, Middlesborough, by the President, Mr. Jones]:—

Iron is one of the most widely-diffused of the elementary substances composing the solid crust of the globe, and as this is a locality in which the metal is separated from the ore on an extensive scale, it may be useful and interesting if we endeavor to trace its more important geological relations. The subject of this paper may be considered under two heads—first, the mineral combinations of iron; and, second, the influence of these in the production of geological phenomena. Iron rarely occurs in a native state, but is mostly found in combination with oxygen or sulphur. With the former it produces—(1) protoxide of iron, which is usually found in combination with other substances, forming portions of many igneous rocks, carbonate of iron, etc.; (2) peroxide of iron—known under the names of red hematite, specular iron ore, and brown hematite, which latter is the oxide in a hydrated form; (3) magnetic, or black oxide of iron—a combination of the protoxide and peroxide. With sulphur, iron forms (1) common iron pyrites; (2) white iron pyrites; (3) magnetic pyrites; (4) arsenical pyrites. The metal also occurs in connection with chromium as chrome iron ore; with titanium as ilmenite; with tungsten as wolfram; with silica, and with other substances, forming more or less important combinations, though it is only the commoner forms that play an important part in a geological sense.

We now proceed to consider the relations of iron as a constituent of rock masses. Though there is no particular reason why we should commence our examination with the igneous rocks, as these belong to all geological periods, it may be best if we take this division of rock masses first. In igneous rocks, of whatever age, we find iron is a constant constituent, in some varieties really reaching a comparatively high percentage. Having regard to the relations of the igneous rocks to the internal composition of the globe, it is reasonable to assume that this element is as widely distributed in those impenetrable parts of the globe which science is not likely to open out to human investigation, as it is throughout the igneous and aqueous deposits, which may be studied upon, or near to, the surface. It seems almost certain that the iron now found, in even the oldest sedimentary rocks, was originally derived from the disintegration of the earliest fire-formed rocks, the origin of which, in the present state of our knowledge, is involved in much obscurity.

The lowest sedimentary deposits are comprised in what are termed the Laurentian and Cambrian systems. Here we have a fast thickness of shales, sandstones, and limestones, which are for the most part colored some shade of blue, which indicates the presence of protoxide of iron in the waters in which these ancient rocks were laid down. Our common roofing slates from Cumberland, Westmoreland, and Wales, may be taken as typical examples of the tint which prevails in the system under notice. In

some of the more arenaceous beds of the series, there is a comparative absence of color, probably due to the more rapid formation of these strata, and the consequent wide diffusion of the iron contained in the ocean at that period. At other times, however, very large quantities of iron appear to have been carried into the Cambrian seas, for we find in some places large deposits of oxide of iron in connection with the rocks of this age.

In the Silurian strata the prevailing tint is some shade of blue—that is, in the native condition of the rocks, as all masses which owe their color to protoxide of iron weather into a brown color on exposure to the atmosphere. In the British area a comparatively small amount of iron was present in the ocean of the Silurian period. It is noticeable that about the middle of the system we find a small mass of sandstone, which is colored with red oxide of iron, and resembles, to some extent, one of the divisions of the Old or New Red Sandstone proper. Towards the close of the Ludlow age, when the Silurian seas teemed with the abundant forms of organic life that existed at that time, a comparatively sudden change occurred in the proportion of iron mixed up with the slowly accumulating sediment. What geologists have denominated "passage beds"—indicative of a gradual change from the life forms of the Silurian age to those of the overlying Old Red Sandstone, or Devonian period—are highly colored with the red oxide of iron, and the same general character marks, in a higher or lower degree, the succeeding measures, forming collectively the Old Red and Devonian of England, Scotland, and Ireland.

The carboniferous system, which comes next in ascending order, presents us with immense deposits of limestone and shale, colored by protoxide of iron; a great thickness of coarse sandstone, only slightly colored; and the coal measures proper, the shales of which are not only tinged blue by the lowest oxide of iron, but the quantity of this substance was in some places so abundant as to lead to its being separated from a state of solution and segregated into nodular masses, which have formed most valuable seams of ironstone in Staffordshire, Shropshire, Derbyshire, South Wales, Scotland, and other districts.

The coal period was, again, succeeded by one in which the seas abounded in peroxide of iron, though a gradual change from the one condition to the other evidently occurred, as several local and intermediate stages can be traced through; for instance, the magnesian limestone formation to the Red Sandstones, sands, and other strata that form the upper Permians. But the New Red Sandstone, or Triassic formation, which succeeds it, is eminently pervaded by the red tint due to peroxide of iron.

From the close of the Triassic period those causes which led to the admixture of peroxide of iron with the sedimentary rocks, ceased to operate on an extensive scale, as far as the area of British geology is concerned; and we may, therefore, dismiss the younger rocks with less minuteness of detail. In the South of England the upper Keuper marls are seen gradually shading upwards into the blue shales and limestones of the lias, and, indeed, in this district the change may be noticed, as the sandstone and marl at Leckenby, forming the upper part of the Triassic series, is decidedly tinged with the protoxide instead of with the peroxide of iron. The lower lias is blue throughout, but the middle lias is more arenaceous; and though in places it contains thick deposits of iron in the form of a carbonate, there is only a comparatively small quantity of iron generally diffused through the strata forming this subdivision. The overlying alum shale is colored by protoxide of iron. The oolitic system consists of slightly colored sandstones, with thick deposits of blue clay intervening, so that whilst considerable quantities of protoxide of iron were present at intervals, the hydrated peroxide never occurred in sufficient abundance to leave much trace upon the contemporaneous sediments. In some places deposits of ironstone were formed, but the diffusion of peroxide was due to causes which only came in operation for periods of comparatively short duration.

The same remarks apply to the fluvio-marine beds of the Wealden. The green sand—lower and upper—contains a good deal of hydrated peroxide of iron, both diffused through the mass, and in more concentrated layers; and in some parts the green silicate of iron surrounds the grains of quartz forming the sandstone,

thus giving rise to the name which this formation bears.

The chalk and tertiary beds are not rich in iron, though this material is found more or less to tinge nearly all the strata up to those most recently formed.

The drift deposits which are found filling up hollows, and covering over the regularly stratified rocks on all sides, are naturally colored various shades of red, from having been derived from rocks in which the peroxide of iron largely prevailed. If, for insstance, this country were again to be submerged, the drift produced by the washing of the ocean over the rocks, masses now occurring upon the surface, would evidently be highly colored by being mixed up with the materials derived from the extensive tracts of New and Old Red Sandstone in various parts of the country.

Having now examined the conditions under which iron occurs in the geological series of rocks, we may briefly notice the circumstances which influence the formation of extensive deposits of iron ore. With respect to the masses of red hematic to be found filling up cavities in certain rocks, as, for instance, mountain limestone of the West Coast, and the Devonian limestone of the southwest of England, it appears that at the commencement of the periods when the sea became highly charged with peroxide of iron, the quantity was at first so great as to be deposited in large masses as sediment at the bottom of the ocean, especially in such cavities as might exist in the newly submerged surfaces, but, that the supply of peroxide was afterwards less, or was more widely diffused, and hence was mixed up with an increasingly large proportion of sand and clay, thus reducing the iron to a mere coloring agent. It is easy to see that any deposits of iron ore, formed under such circumstances, are likely to be comparatively free from impurities of an organic origin, as water charged with iron has evidently been fatal, in a great measure, to the existence of animal life; consequently, the deposits of oxide of iron which may be expected to lie at the base of the old and new Red Sandstone formations may also be expected to be free from phosphorus, and other organic impurities. The mountain limestone on the West Coast was under water during the new Red Sandstone period; hence its important deposits of hematite. It remains to be demonstrated how far this submergence of the mountain limestone underneath the Triassic seas extended. My impression is that it will be found that it was only in the western parts of the country that this submergence occurred; though I believe it affected the limestone from Cumberland to the southwest of England, and that in the mountain limestone of North and South Wales, Somerset and Devon, many parts will yield deposits of hematite. I believe also that it will be found that the limestone of South Devon will yield large quantities of good hematite that have been deposited at an earlier age, that is, when the ancient British seas became, for the first time, highly charged with oxide of iron.

With respect to the clay ironstones of the coal measures, their mode of formation was by segregation round some organic nucleus, and hence it necessarily follows that they are more or less mixed up with organic remains, and the substances they would yield. It also follows that this class of ironstone can only be expected to occur in comparatively thin and irregular layers. The mode of formation of the Cleveland ironstone, and of other somewhat similar deposits, is not yet fully understood, though elaborate theories have been invented to account for the occurrence of such extensive masses of ironstone. The main difficulty arises in accounting satisfactorily for the sudden influx of so much iron into the seas of the period when the oolitic iron ores were formed. Whatever the precise circumstances were, it seems clear that what are now thick seams of ironstone were at first only beds of oolitic sand in an unconsolidated form. The infiltration of the iron, and the changes thus produced, probably took place soon after the original deposition of the matrix in which the carbonate of iron is now found. These remarks apply more or less to the iron ores of the secondary formation. The conditions under which these deposits originated, naturally led to their being largely contaminated with organic remains; and it may be expected that all iron ores found in connection with rock formations, yielding fossils, will be comparatively impure.

The limits of this paper will only allow of a cursory treatment of this important subject; but I have endeavored to draw attention to two points, which, perhaps,

may be suggestive to some members of the section who have time to work them out. First, the purest oxides of iron ore are likely to be found in connection with rocks that were submerged during the earlier geological periods; and secondly, the desirability of ascertaining with tolerable accuracy the limits of this submergence.

LONG SPAN BRIDGES.

From "The Mechanics' Magazine."

An allusion was made in our leading article of last week to the fact that engineers are not so prone to indulge in the erection of bridges of large spans as was the practice some years ago. Experience has since demonstrated that when the bearings between the piers reach a certain dimension, the superstructure becomes more expensive than the substructure. It is not generally known that but for the fear of introducing an awkward curve in the line, the bridge over the Menai Straits might have occupied the site of the Swilly instead of the Britannia Rock, and its present maximum spans would have been reduced by nearly 100 ft. But the engineers of the old school had a mortal dread of steep gradients and sharp curves, and considered their absence cheaply purchased by any other sacrifice incurred in the shape of embankments, cuttings, tunnels, bridges, and permanent works of any description. With their limited ideas of one mile radius for the curves, and one in a hundred for the gradients, what would they have thought of engines being manufactured and almost able to "turn in their own length?" and as for gradients, "going up a ladder" is a mild expression for their climbing capabilities! As with the largest span bridge in England so with that in the sister country. The Boyne Viaduct has a maximum span of 260 ft., and carries the Dublin and Drogheda Railway over the valley of that river at some distance from the town. It is now well understood that there was not the slightest necessity for erecting so expensive a bridge, and that the line could have been taken, to more advantage in every sense, nearer the town, where the valley narrows.

There is no disguising the truth that when iron was introduced as a material eminently adapted for the construction of some of the most prominent of the permanent works of a railway, there was a pardonable rivalry among the members of the profession with respect to erecting bridges of large span. Telford led the way both at home and abroad; Stephenson and Brunel followed, and Fairbairn and others brought up the rear. It is clear that every engineer considered it incumbent upon him to prove what he could do with iron, and many structures of that material, hideous in appearance, with proportions in mockery of science, and a distribution of metal betraying an utter and reckless ignorance of the knowledge of strains and strength of materials, attest to the present day the manner in which some of the profession displayed their ability. To such a pitch did their incompetency attain, that, after many fatal proofs of it, a Royal Commission was appointed to inquire into the "Application of iron to railway structures." The whole subject was then thoroughly sifted, the aid of the mathematician was called in to supplement that of the engineer, and the result was the establishment of certain laws and regulations which, if they could not instruct the ignorant, could, at any rate, protect the public from the consequences of their ignorance.

Admitting that bridges of large spans have been erected in positions in which it has been subsequently demonstrated there was no absolute necessity for them to occupy, it must not be understood, on the other hand, that the necessity for a bridge of large span may not arise. There are manifestly numerous localities which roads and railways are ultimately destined to traverse, possessing physical features incapable of being surmounted by any other means. To be of any value, railway intercommunication between any two points must be continuous. The chain must be perfect. The absence of one link is fatal to the whole. Should a ravine, a mountain pass, a chasm, or a hiatus of any kind intervene along the route, it must be bridged, and the size of the span must obviously depend upon the number of piers or supports that it is possible to

erect on the sides and bottom of the gulf. This brings us to the question of the maximum span that it is possible to obtain by any known principle of scientific construction, and just at the present time it has a peculiar interest bearing upon the proposed international bridge over the Channel. We are not about to advocate any particular scheme or discuss the merits of any proposed method for accomplishing the transit between the two shores. Our readers will find full information upon this point in a paper published in our recent numbers. The only method to which our article has any reference is that of M. Boutet; but, were we inclined to advocate the project, we have not the slightest evidence which would enable us to form any opinion of its theoretical or practical feasibility. In the following investigation no notice will be made of stone arches, as their maximum span does not exceed 200 ft., although that principle, being the oldest, has the first claim to consideration. It was, in fact, the original principle proposed by Stephenson upon which to execute the bridging of the Menai Straits. There is no necessity to refer to the reasons why that design was abandoned, because it had to do with other considerations, which reflected not the shadow of doubt respecting the practicability of the project. Neither is there any necessity for our present purpose to advert to the scheme in detail. It is sufficient to state that the maximum span in cast-iron was 360 ft. So far as theoretical construction is concerned, there is no limit to the span of an arch or suspension bridge; but, in spite of this, the former type has almost become obsolete for spans exceeding 200 ft., and the latter has never yet been successfully applied to railway traffic. By railway traffic we do not mean the drawing of carriages, or the crawling of a locomotive over a bridge, but the passage of an express train, or limited mail, at full speed. Here we notice the difference between theory and practice. Stephenson considered that if he increased his cast-iron arch to a span of 460 ft., as he contemplated, the rise of the crown due to expansion and contraction would present a difficulty that he would be unable to provide for. This was no doubt an erroneous impression, as he would have found had not the contingencies imposed by the Admiralty compelled him to abandon the arch principle altogether, and seek for a solution of the novel engineering problem in the adoption of different means. Without inquiring into the relative suitability of cast and wrought iron for the construction of arches, it may be taken for granted that 500 ft. will represent the practical limit to the span of an iron arch.

The next type that deserves consideration is that in which the horizontal strains are resisted by the various members of the structure itself, and a vertical pressure alone transmitted to the supports; and the Menai Bridge certainly ought to be mentioned first. The question therefore is, what is the limit to the span of a tubular bridge? All bridges which are self-containing with respect to the strains exerted upon them, come under the denomination of beams, and the limit of their spans is based upon the fact that the strength is as the square, and the weight as the cube, of their lineal dimensions. The weight of a tubular or solid-sided girder increases far more rapidly with an increase of span than that of the lattice or open web type, in consequence of the large amount of metal required as stiffening irons. About 21 per cent. of the whole material in the Menai Bridge was absorbed in stiffening the sides. The question of determining the maximum possible span of girders becomes very complicated, because by the employment of steel instead of iron, much larger spans could be obtained. At the same time there are no practical examples upon which to base a reliable calculation. It will be safer, then, in the present instance, to deduce our conclusions from what has been already accomplished with a material that is trustworthy, than to hazard conjectures respecting what might be done with another that has not yet been tried. The ultimate span reached by steel would not probably exceed that attained by iron by more than 30 per cent. A tubular girder would not practically exceed the limit of 600 ft. as the maximum span, and if of steel, might reach 800 ft. There is very little doubt that, with the exception of Dr. Fairbairn, the great advocate for solid-sided girders, no engineer would ever again employ the tubular system. A glance at the recently erected railway bridges of large spans, points out unmistakably that the open web principle has superseded the older and the more cumbrous one. Larger spans would be more practicable upon the

open web or lattice principle than upon that of its predecessor. A lattice girder would probably reach a span of 800 ft., if constructed of iron, and of 1000 ft., if steel were employed. Whatever particular form of horizontal girder might be adopted, it may be safely laid down that the maximum span attainable with any material would not be less than 1,000 ft., or, in round numbers, the fifth part of a mile. It must not be considered that we are advocating the economy of bridges of five spans to a mile; we are simply demonstrating their possibility.

The only system to be now alluded to is the suspension, which, so far as mere length of span is concerned, decidedly occupies the first place. Arguing analogically from the size of the existing spans of suspension and horizontal girders, and calculating proportionally, the limit to the span of a suspension girder would be 1,700 ft. The maximum limit, under any circumstances, might be put at 2,000 feet, or about double that attainable by the other type of bridge. Besides these ordinary principles of construction, there are others, such as those of Von Rupert, M. Boutet, and other engineers. With respect to these it should be borne in mind that while on the one hand there are unfortunately no practical data to be guided by, yet there is no valid reason why it may not be possible to achieve larger spans than have hitherto been attempted. The proper line of argument to adopt, and method of testing any of these novel schemes to be employed, is to follow the plan pursued in the case of the Britannia Bridge. Those who believe in the practicability of spans of nearly a mile in length, should have a model constructed to an actual reduced scale of the bridge which is to serve the purpose. It should be broken, put together and broken again, until the best proportions were thus experimentally arrived at. Calculations of the breaking weight and the strains upon the various parts could thus be accurately worked out, and the truth of theoretical formulæ either verified by empirical results, or modified as might be necessary. This is the only plan by which to satisfy professional men and judges of such matters. The mere drawing of a design upon paper, and the results of mathematical investigations alone, are not sufficient to justify any confidence in a novel principle of engineering construction.

The Director-General of the Ordnance and the Committee of Inventions at Woolwich have under trial a bottle cartridge designed by Colonel Boxer. It is intended, if successful, to supersede the ordinary cartridge in use for small-bore breech-loading rifles, which cartridge, being several inches in length, is very liable to injury. The main principle of the invention is to enlarge the chamber of the rifle without interfering with the diameter of the barrel. The cartridge is, therefore, in the shape of a bottle, the apex or neck containing the bullet, while the base consists of the powder, which, being concentrated more than in the elongated cartridge, is theoretically supposed to possess the property of more rapid ignition and consequent increase of force. All the advantages which attach to a "low trajectory" are, therefore, claimed for the invention, which is not so new as is generally supposed, having been introduced some years since in America. We have had by us for the last five years copper-cased bottle-shaped cartridges for the Spencer repeating rifle.

How to Bleach Ivory. — A process for bleaching ivory is given by Dr. Artus. He especially mentions the application to ivory plates for pianoforte keys; but it will of course be applicable to all articles of the material, which is so liable to acquire a disagreeable dark color. The articles are first to be soaked in a solution of carbonate of soda ($\frac{1}{2}$ lb. of the crystals to 2 lbs. of water) for a couple of days. They are then to be well rinsed with clean water and afterwards transferred to a solution of $\frac{3}{4}$ lb. of sulphate of soda in 2 lbs. of water, in which they must remain for 5 or 6 hours. Then, without removing the ivory, a mixture of 1 oz. of hydrochloric acid and 4 oz. of water is to be added, the whole is to be stirred together and the vessel covered up and left for 36 hours. At the end of this time, the solution is poured off and the ivory is to be well washed with water. If it should not have the desired whiteness the process may be repeated. The proportions of solutions we have given above will suffice to bleach 1 lb. of ivory.—*The Workshop.*

APPARATUS FOR MEASURING THE VELOCITY OF SHOT.

DESIGNED BY CAPTAIN W. H. NOBLE, R. A.

From "Engineering."

The instrument consists of two portions: first, the mechanical arrangement for obtaining the extremely high speed of the recording surface, and maintaining that speed uniform; and second, the electric apparatus for registering upon this surface the exact instants of time at which the shot passes certain stated points in the bore of the gun.

The first part of the instrument, for obtaining a very high and uniform speed of the recording surface, consists of a series of six thin metal discs, each 36 in. circumference, fixed at intervals upon a horizontal revolving shaft, which is driven at a very high speed by a heavy descending weight, arranged according to a plan originally proposed by Huyghens, through a train of gearing multiplying 625 times. If the speed of rotation of the discs were got up through the action of the falling weight alone, a very considerable waste of time would be occasioned; and to obviate this inconvenience, a special arrangement is provided for obtaining approximately with great rapidity the required velocity of the discs, by means of a hand-wheel connected temporarily with the gearing. The sound emitted by the rapid rotation of the disc and gearing serves as an indication of the uniformity of speed, a very slight variation in speed being sufficient to alter the acuteness of the sound to an extent that is readily detected by the ear. The actual velocity is ascertained by a clock connected with one of the slower wheels of the train; and the time of making each 5 revolutions of this wheel, or 625 of the discs, is shown correct to $\frac{1}{10}$th of a second by the clock. The speed usually employed in the working of the instrument is about 1,000 in. per second lineal velocity at the circumference of the revolving discs, so that each inch travelled at the circumference of the discs at that speed represents one-thousanth part of a second; and as the inch is subdivided by a vernier and magnifying eye-piece into a thousand parts, a lineal representation at the circumference of the discs is thus obtained of intervals of time as minute as one-millionth of a second. As a minute variation in speed would make a difference in measurement at the circumference of the discs, the uniformity of rotation maintained by the descending weight is tested on each occasion of experiment by three observations—one immediately before, one during, and one immediately after the experiment, the mean of these being taken for the average speed during the experiment. With a little practice, there is no difficulty in managing the instrument so that the discs may rotate either quite uniformly or at a rate very slowly increasing or decreasing; and it is found that the probable error then arising in the determination of the time occupied by 625 revolutions of the discs rarely amounts to so much as $\frac{1}{10}$ of a second, the total time of making each 625 revolutions being about 23 seconds. The uniformity of revolution during each experiment may consequently be considered practically perfect, as the total time of observation in the passage of a projectile along the length of a gun is generally less than one-third of a single revolution of the discs. The maintenance of the speed with so great a degree of uniformity is obtained by means of very great accuracy of workmanship in all parts of the mechanism.

For accomplishing the second portion of the operation, namely, the registering of the exact instants of time which it is desired to determine, the six revolving discs are each covered on the edge with a strip of white paper, and are all in connection with one extremity of each of the secondary wires of six electrical induction coils; the other extremity of each secondary wire, carefully insulated, is brought to a discharger opposite the edge of its corresponding disc, and is fixed so as to be just clear of the revolving disc. When an electric spark is passed from one of the wires to its corresponding revolving disc, a minute hole is perforated in the paper covering on the edge of the disc, marking the point of the disc that was opposite to the wire at the instant of the spark passing; but as the situation of this hole in the paper would be very difficult to find on account of its extreme minuteness, the paper is previously black-

ened over with lampblack, and the position of the hole is then readily seen by a distinct white spot being left on the blackened paper on the edge of the disc, in consequence of the lampblack at that point having been burnt away by the electric spark, so that the white paper is shown beneath. As the points of the six wires at the edge of the discs are all arranged in the same horizontal straight line, parallel with the axis of the revolving discs, an absolutely simultaneous passage of the six electric sparks causes the sparks produced upon the six disks to be all exactly in the

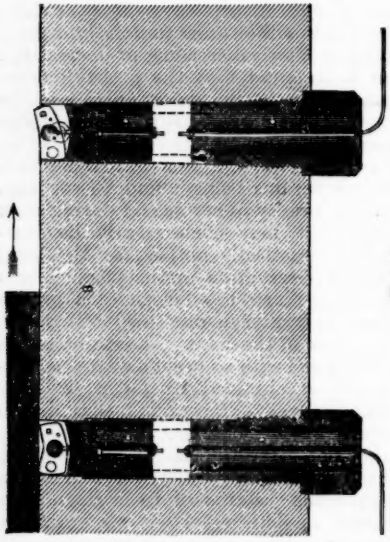
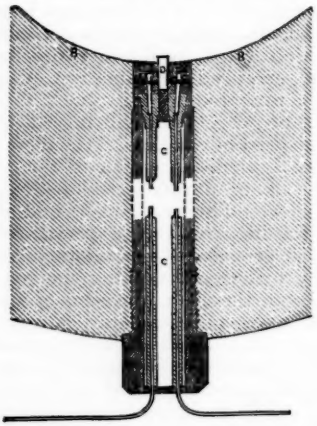


Fig. 1.

same horizontal straight line, at whatever speed the discs may revolve; but any interval of time is represented by a corresponding circumferential distance between the spots on the different discs, this distance being proportionate to the speed at which the discs are revolving. Thus, when the discs are revolving at the circumferential speed of 1,000 in. per second, an interval of $\frac{1}{1000}$th part of a second of time between any two of the sparks causes the spots made upon the two corresponding discs to be separated by a distance of 1 in., measured at the circumference of the discs.

The mode of connecting the primary wires of the induction coils to the bore of the gun in such a manner that an electric current shall be induced, and a spark produced at the instant of the shock, passing each wire in succession, is shown in Figs. 1 and 2, representing a longitudinal and a transverse section of the bore, B, of the gun, along which the shot, A, is moving in the direction of the arrow. A hollow plug, C, is screwed into the side of the gun, carrying at its inner extremity a hinged finger, D, forming a trigger, which is made with an incline at the tail end, projecting slightly within the bore of the gun, as shown in the right side in Figs. 1 and 2. The trigger is held up in this position by the primary wire, which passes in at one side of the plug, C, then through

Fig. 2.



a hole in the trigger, D, and out again at the other side of the plug. When the shot is fired it pushes the trigger, D, outwards, as shown on the left side in Fig. 1, and thereby cuts the wire through, and the consequent breaking of the current in the primary wire induces a current instantaneously in the secondary wire, causing an electric spark at the same instant to pass from the point of the wire to the disc, its passage being marked by the spot left on the paper edge of the disc.

The St. Petersburg Exhibition in 1870.—This exhibition is confined to Russian produce and manufactures; it is national, and not international, as has been stated in some publication. It is to open on the 27th of May, and close on the 27th of July.

HOISTING APPARATUS.

From "The Building News."

To the builder, no contrivances for economizing or facilitating labor are of greater interest than those adapted for raising heavy weights. The advantages obtained by the use of hoisting apparatus come principally under two heads, namely:—concentration of power, and actual saving in the weight to be raised. The concentration of power may be obtained in the case of manual hoists in two ways: either one or two men may lift a weight which many men would otherwise be required for, or a number of men may unite their strength with greater facility than they otherwise could. The saving in the weight actually raised arises chiefly from the fact that the men using any kind of hoisting gear remain stationary; while in other cases they ascend ladders or inclined planes. Thus the weight of the laborer is saved in each "lift" of the apparatus. A further saving can often be effected by counterbalancing the buckets, trucks, or other gear used to contain the material lifted. In using hoists worked by "power," there is the same saving of weight and concentration of power, with the further economy arising from the difference between the cost of steam or water power and manual labor. Amongst hoisting apparatus we have: (1) pulley-blocks of various kinds: (2) differential ditto; (3) windlasses; (4) single and compound crabs; (5) cranes of various kinds; (6) capstans; (7) derricks; and (8) travellers. All these can be wrought by hand, and to most of them steam power has been applied. The amount of ingenuity expended on the improvement of hoisting gear has been very considerable, and the resulting contrivances are very various.

A short history of the progress made, and an explanation of the principles involved in this branch of constructive art, cannot fail to be interesting and profitable to our readers, so much of whose business lies in dealing with the proper raising of weights. In order to treat the subject in an intelligible manner, it will be necessary to commence with a consideration of the mechanical principles on which all are alike founded.

It must be distinctly borne in mind that no mechanical contrivance can create power, or increase it; it can only be modified in various ways. For convenience of illustration let us take 1 lb., 1 ft., and 1 minute, as standards respectively of weight, height, and time. It is evident that if 1 lb. be raised through a height of 1 ft., a certain amount of work is done, no matter in what length of time. It is equally evident that a proportionate amount of power must be exerted to do this work, and the absolute amount of such power is also independent of the time taken to do the work. Further, supposing 10 lbs. be raised in place of 1 lb., also through 1 ft. in height, 10 times the work is done; and if 1 lb. be raised 10 ft., it follows equally that 10 times as much work is done as in the first case. We arrive therefore at this first principle—that the work done is in direct proportion to the weight raised, and in a like proportion to the height through which it is raised. We see also that since the raising of any given weight to any given height represents always the same amount of work, and therefore the same amount of power, the work done and the power consumed are alike independent of the question of absolute time. But still it is evident that, as the work must be accomplished in some portion of time, the element of duration and speed must be considered. This seems almost to lead to a paradox, namely, that power is at once dependent on and independent of time. A very simple comparison will, however, clear up the difficulty. Let us take the case of a tank or vessel to be filled with water by a small pipe. Let us for further suppose that 1 ft. in depth of water in this vessel will weigh 1 lb. Now we have here something analogous to the compound standard, the foot pound, before mentioned; and it is evident that the size of the pipe by which the water is run in will affect the question of time only—that is to say, that when the vessel is filled, for 1 ft. of its depth there will be 1 lb. of water in it, whether such water has been run in by a pipe of $\frac{1}{16}$ in. or 1 in. bore. In the first case the time would be 256 times as long as in the second, because the supply coming through a tube of $\frac{1}{16}$ in. is only $\frac{1}{256}$ of that fur-

nished by one of an inch bore. On consideration, therefore, it will be seen that the filling of the tank is also apparently at the same time dependent on, and independent of, the bore of the supply-pipe ; and a little further consideration will show the analogy between the case of the water and that of the power. The comprehension of this general principle is necessary to the proper understanding of hoists of all kinds, and cannot fail to be of use to the reader in selecting apparatus the best suited to each case that may rise, namely: Whatever is gained in power must be lost in speed ; and *vice versa*. Therefore a man must necessarily take twice as long to raise 2 tons weight to any height as to raise 1 ton to the same elevation ; and no hoisting apparatus, however constructed, can in the least modify this law.

In selecting hoisting apparatus it is requisite to consider the weight to be lifted and the rate at which it must rise, and also the power of each man. Now the power of an ordinary laborer is about equal to the raising of one ton through one foot per minute. If, therefore, it is required to raise 1 ton at the rate of 1 ft. per minute—no matter what height—one man can do it. If at the rate of 2, 3, or 4 ft. per minute, 2, 3, or 4 men must be employed, and the hoisting apparatus chosen accordingly. If the rate at 1 ft. per minute remains the same, but the weight be increased to 2 or 3 tons, then 2 or 3 men must be engaged at gearing to suit the case. Simple and apparently obvious as these principles are, many cases occur where they are overlooked, to the great loss of those so forgetting the old saying *Ex nihilo nihil fit.* If these facts were more generally understood, we should hear less of So-and-so's Patent Quadruple Purchase Blocks for "gaining power and speed." Having thus far cleared the ground, we can proceed to examine the best contrivances hitherto introduced for hoisting purposes.

Of ordinary pulley-blocks it is not necessary to speak, as their specialties are generally known. We shall commence with differential pulleys. The principle of the differential pulley has been known from time immemorial, and, like other inventions hidden in obscurity, such as the compass, gunpowder, etc., its invention has been attributed to the Chinese. Be this as it may, its first application was by means of a windlass of differential diameter. On this windlass a rope was coiled partially on the larger, and partly on the smaller diameter. A part of the rope between the two diameters being allowed to hang down in a loop, a pulley was placed in such loop. If the windlass were turned in the direction necessary to cause the winding of the rope on to the larger diameter, it would at the same time unwind from the smaller; and if turned in the contrary direction, the rope would be wound on to the smaller as it was unwound from the larger. The pulley in the loop between the two diameters would therefore only rise or fall by half the difference between the length of rope taken up by one diameter and that given off by the other. Taking a case where the larger diameter was (say) 12 in., and the smaller 11 in., the respective circumferences would be 37.69 in. and 34.59 in. Speaking roughly, therefore, there would be a difference of 3 in. in one turn of the windlass. The movable pulley divides this difference by 2, so that for each turn the weight hung to the pulley would only rise or fall $1\frac{1}{2}$ in. Supposing a winch handle at each end, having radii of 18 in., two men working continuously for eight hours per day could raise with this windlass no less a weight than 1 ton through 3 ft. per minute ; and for a short time, even much more than this. Such contrivance is therefore so simple and so powerful that some urgent reason must have existed to limit its use, otherwise it would surely be more common than it is. Such a cause does exist in the excessive length of rope required; for instance, in the case just cited no less than 25 ft. of rope would be required to effect a lift of 1 ft. As might be expected, many attempts were made to overcome this inconvenience. These attempts all lay in one direction, namely to use a chain in place of a rope, and to make it act as an endless chain, by uniting the end from the larger diameter to that on the smaller. Pins were proposed to keep hold upon the chain, but were found useless; and all attempts failed till Mr. T. A. Weston introduced the now celebrated blocks which bear his name. In these blocks, the sheaves have recesses on the peripheries to fit the links of the chain, such recesses as the chain would make

if wrapped round a disc of clay or putty, and the chains are made with special care to insure the equality in size of the links. These blocks, as is well known, will not run down. They are therefore admirably suited for lifting castings and forgings on to machines or carts, and for lifting wrought or rough stones into any desired position, complete command over the load being attainable. They are not suited, however, for long lifts. That they supplied an urgent want may be gathered from their extensive and rapid adoption, there being at the present time perhaps sixty thousand sets in use. In these blocks an "improvement" known as Hardcastle's was made, to effect quick lowering by disengaging the two sheaves; but it has not proved a success in practice, this want of success arising chiefly from the fact that at the low lifts for which Weston's differential blocks are suited, the quick lowering does not compensate for the extra complication and trouble. In the blocks known as Eades's epicycloidal a different action is adopted, namely, a spur wheel running round inside an internally toothed wheel. The construction—which is difficult to convey in words—is such that while the spocket wheel revolves rapidly, the chain barrel goes very slowly; a very considerable increase of power can be obtained with these blocks, but of course only by a corresponding sacrifice of speed. There are also the several constructions of blocks introduced by Mr. Pickering. When we come to higher lifts than these several systems of blocks are suited for, the windlass and crab come into requisition. The ordinary constructions of windlasses and crabs are too well known to need any special description, and their principle of action is that already explained, the sacrifice of speed to gain power. To Mr. Weston we are indebted for the introduction of his friction coupling and brake, and his inclined "nip." These highly ingenious and scientific appliances have effected an advance in hoisting apparatus greater than any hitherto made. The extreme convenience and safety resulting from their use make them worthy of a fuller description than we can give in this article; we shall therefore reserve our remarks upon them for a future occasion. Amongst cranes we have every variety, from small manual power cranes to ponderous machines wrought by steam or hydraulic power. Hydraulic cranes have not as yet been applied to building purposes, though for the heavier kinds of construction they offer very great advantages. Steam cranes and derricks are largely employed, though not to the extent they might be. For the builder's purpose, however, the overhead traveller offers the greatest advantages, enabling every part of a building to be reached with ease, and ponderous masses of stone and iron to be placed in position with certainty, ease, and dispatch. The distinctive feature of the traveller consists, of course, in its possessing two rectilinear movements at right angles to each other. The one movement is effected by a main traveller moving on rails laid on an elevated scaffolding on each side of the site of the intended building. On the main traveller are laid rails on which the secondary traveller can move at right angles to the course of the main one. This secondary traveller carries the crab or hoist, and the means of hauling the small traveller backwards and forwards on the large one. The main traveller is provided with gear suited to traverse itself upon the line of rails first mentioned. The construction of the crab is one of the most important parts of the *tout ensemble* of a good traveller, as upon its action depends greatly the facility with which the masses lifted can be placed. The crab should be subject to the minimum amount of friction, must sustain its load at any point, and be capable of expeditious lowering under complete and instantaneous control. It is always a source of danger to have crabs in which the handles must be either used for lowering—in which case much time is lost—or in which they must revolve in a reverse direction, though not actually used; as in the latter case many accidents are likely to happen from their striking the men. It is far easier to lower a load—either small or great—by the controlling power of an efficient brake, than by any other means; in addition to this ease, an amount of safety and convenience otherwise unattainable is secured. The great difficulty hitherto has been to obtain a brake of ample power, instantaneous in action, requiring but a slight exertion on the part of the operator, and last, but not least, in a small compass. Such brakes are now, however, in very common use in

warehouses, docks, iron-works, etc., and builders will doubtless soon appreciate the advantages to be obtained by their adoption.

THE SCHINZ BLAST FURNACE.

From "Engineering."

In blast furnaces worked in the ordinary way with solid fuel, from 60 to 70 per cent. of the waste gases usually consist of nitrogen, and the quantity of this gas which is evolved from the mouth of the furnace may be taken as averaging from 5 to 6 tons per ton of iron made. Now, the heat carried off from the furnace by this nitrogen can only be utilized—and then only partially—by the employment of such arrangements of blast-heating stoves and boilers, heated by the waste gases, as will enable these latter to be ultimately discharged at a lower temperature than they leave the blast-furnace. If, for instance, the waste gases leave the blast-furnace at a temperature of 600°, and, after passing the boilers and blast-heating stoves, are ultimately discharged at a temperature of 400°, there will have been abstracted from them the heat due to the reduction of their temperature by 200°, this being of course in addition to the far greater amount of heat generated by the combustion of the carbonic oxide which the waste gases contain. In this way a portion of the heat carried off by the nitrogen from the blast-furnace may be utilized, but the greater part is eventually wasted. Let us suppose, for instance, a blast-furnace discharging $5\frac{1}{2}$ tons of nitrogen per ton of iron made, and let this nitrogen be finally discharged at a temperature of 400° above the ordinary atmospheric temperature. In this case we have $5\frac{1}{2}$ tons=12,320 lbs. of nitrogen heated 400°, and as the specific heat of nitrogen is .244, this corresponds to the carrying off of $12{,}320 \times 400 \times .244 = 1{,}202{,}432$ units of heat. It has been estimated by Mr. Siemens, that on an average each lb. of coke consumed in a blast-furnace generates 6,000 units of heat, and assuming this estimate to be correct, the heat carried off by the nitrogen in the above instance would be equal to that evolved from $\frac{1{,}202{,}432}{6000} = 200.405$ lbs., or about $1\frac{3}{4}$ cwt. of coke per ton of iron made.

In addition to the heat carried off by it, the nitrogen passed through a blast-furnace appears to do harm to a certain extent, by diluting the effective gases, and rendering the action of the carbonic oxide on the oxide of iron somewhat less energetic than it otherwise would be. To avoid these inconveniences and reduce the amount of nitrogen passed through any given furnace, Herr Charles Schinz, of Strasbourg, a metallurgist who has made the action of blast-furnaces his special study, has designed a method of working such furnaces partly with solid fuel in the ordinary way, and partly with carbonic oxide manufactured in separate generators, and forced in through independent tuyeres with the blast. As yet we are unaware that Herr Schinz's system has been tested on a practical scale; but we nevertheless think that it is at least worthy of the attention of those of our readers engaged in the iron manufacture, and under these circumstances we propose to describe it.

The theoretical principles on which Herr Schinz's system is founded may be very briefly stated. When a volume of carbonic acid is carried over coals, or over any substances containing carbon in a state of incandescence, half a volume of carbon will be absorbed, and two volumes of carbonic oxide will be formed. In the blast-furnace carbonic acid is invariably formed in the first instance, and when there is an excess of carbon present, this carbonic acid becomes transformed into a double volume of carbonic oxide. But in this case the resulting carbonic oxide is invariably mixed with that quantity of nitrogen which is due to the oxygen contained in the atmospheric air which has been used during the process of combustion, and it amounts to 3.77 volumes for each volume of oxygen. Therefore, two volumes of carbonic oxide + 3.77 volumes of nitrogen are formed in the first instance, and these, by the process of combustion, are converted into two volumes of carbonic acid + 7.54 volumes of nitrogen; whilst by Herr Schinz's process, which we shall hereafter describe, the gas

intended to be used for the purpose of combustion consists of only two volumes of carbonic oxide, which, through the process of combustion, produce two volumes of carbonic oxide + 3.77 volumes of nitrogen. In the application of Herr Schinz's system to blast furnaces, the carbonic oxide is, as we have said, injected simultaneously with the atmospheric air through separate tuyeres upon the incandescent fuel, so that the combustion of the carbonic oxide is effected in the very midst of the fuel, namely, in the hearth, where, owing to the presence of an excess of carbon, and through the resulting high temperature, the carbonic acid, which is one of the products of combustion, is again transformed into carbonic oxide. In this case, therefore, we obtain four volumes of carbonic oxide, and only 3.77 volumes of nitrogen; and Herr Schinz estimates that by the adoption of his system, the proportion of carbonic oxide in the waste gases may be increased nearly one-half, or about 48 or 49 per cent. of its present amount.

Before describing a furnace fitted up on Herr Schinz's system, we must say a few words respecting the manufacture of the carbonic oxide used as fuel. Herr Schinz considers that the most simple as well as the most economical method of generating carbonic acid on a large scale, is the decomposition by heat of the carbonate of lime (limestone), the residuary product of which in the shape of burnt or quick lime, finds nearly everywhere a ready market. The burning of the limestone is conducted in retorts or muffles, which are mounted in ovens of a peculiar construction, and the size of which is determined by the amount of carbonic acid given off by the limestone intended to be used, as well as by the quantity required in a given time. At a temperature of 1800° Fahr., the decomposition of the carbonate of lime requires about two hours. One cubic metre (35.316 cubic feet) of carbonic acid contains .5364 kilogrammes (1.18 lbs.) of carbon; and one kilogramme (2.2 lbs.) of carbonate of lime yields .44 cubic metre (15.54 cubic feet) of carbonic acid. Herr Schinz's object being to replace one-fourth of the carbon which serves the purpose of combustion in any furnace by the carbon contained in the carbonic acid derived from the decomposition of limestone, the quantity of carbonic acid required, for instance, for a furnace consuming 100 kilogrammes (220 lbs.) per hour will be = $\frac{100}{4}$ kilog. = 25 kilogrammes (55 lbs.); therefore, 25 kilogrammes = 46.6 cubic metres (1645.7 cubic feet) of carbonic acid must be produced per hour. Now if one kilogramme of carbonate of lime yields in two hours .44 cubic metre (15.54 cubic feet) of carbonic acid, it follows that for each cubic metre of carbonic acid, 4.545 kilogrammes (10 lbs.) of limestone must be under decomposition, and the capacity of the retorts or muffles must therefore be 211.8 kilogrammes (466 lbs.) or .163 cubic metres (5.75 cubic feet).

The carbonic acid gas thus produced is subsequently, in order to convert it into carbonic oxide, carried through a series of other retorts or muffles disposed in the same oven as those in which the limestone is burnt, and which are filled with small refuse pieces or particles of coke, or other combustible material in a state of incandescence. For the calculation of the requisite capacity of these retorts or muffles, the following experimental results will serve: .00474 cubic metres of carbonic acid per hour, requires at the temperature of 1800° Fahr., 1 square metre (10.764 square ft.) of contact surface for its conversion into carbonic oxide; therefore 1 cubic metre (35.316 cubic ft.) of carbonic acid per second requires to be brought in contact with 210 square metres (2260.44 square ft.) of surface presented by the pieces or particles of coke. The effect and determination of the contact surfaces of various kinds of fuel have been closely investigated by Herr Schinz; we cannot, however, follow his investigations here, but shall merely deal with his results. According to the abovementioned example, where 46.60, or say 47, cubic metres (1,160 cubic ft.) of carbonic acid are supposed to require conversion into carbonic oxide, we have $\frac{47}{3600}$ = .013055 cubic metre per second, whence by the equation .00474 : 1 : : .013055 : 2.754, we should have to provide for a minimum contact surface in the retorts or muffles of 2.754 square metres (29.65 square ft.). Herr Schinz states that 1 cubic metre (35.316 cubic ft.) of fuel in pieces of the following dimensions, offer respectively the undermentioned contact surfaces, viz.: pieces of 1 centimetre (3.937 in.) diameter offer 314 square metres (3,379 square ft.,) those of 2 centimetres (7.87

in.) diameter offer 157 square metres (1,689⅓ square ft.,) and those of 3 centimetres (11.8 in.) diameter offer 104 square metres (1,119 square ft.). These figures show that, supposing the capacity of the retorts in which the carbonic acid is to be reduced, were to be made 30 times as large as they are absolutely required to be, in order to avoid the too frequent feeding, they would nevertheless be of a very moderate size. On extending these calculations to the requirements of a blast-furnace having a consumption of 900 kils. (1,980 lbs.) of carbon per hour, it will be found that 225 kilogrammes (495 lbs.) of this quantity would have to be supplied in the shape of carbonic oxide, of which consequently 420 cubic metres (14,833 cubic ft.) would have to be produced per hour. In this case the retorts or muffles required for decomposing the limestone must have a capacity of 1,4423 cubic metres (50.9 cubic ft.), and those intended for the reduction of the carbonic acid $30 \times .3 = 9$ cubic metres (318 cubic ft.), supposing the pieces of coke with which they are filled be small enough. This comparatively small size of the retorts or muffles, admits of their being heated to 1800° Fahr. by the waste gases evolved from the blast-furnace.

The carbonic oxide gas thus formed, is conveyed into a gasometer, dimensions of which must be adapted to the size of the works, and from this reservoir it is supplied to the blowing engine, and thereby forced into the blast-furnace. At the same time atmospheric air is supplied by means of another blowing engine, and this in such a manner that the proper relation between the volumes of gas and air is strictly maintained. The tuyeres employed by Herr Schinz are concentric; those placed internally serve for the conveyance of the gas. It is necessary during their progress to heat both the gas and the air to 750° Fahr., for the purpose of maintaining the temperature produced by the combustion at an elevation which shall be sufficient to convert the carbonic acid into carbonic oxide; but as the volume to be injected is much smaller than it would be under ordinary circumstances, it is possible to accomplish this by the blast-furnace gases.

Of the total amount of fuel expended in working a blast-furnace on his system, if the waste gases were not utilized, Herr Schinz estimates that one-half would be mixed with the other materials in the ordinary way, whilst one-fourth would be used in the retorts in converting the carbonic acid into carbonic oxide, and the remaining one-fourth in heating the retorts. This last quarter part can be saved by heating the retorts by the waste gases, while the fourth used in the retorts may be small coke, which would not be fit for use in the blast-furnace, and which is therefore of less value than that employed in the latter. In conclusion, we cannot do better than recommend those of our readers who are interested in blast-furnace improvements, to read Herr Schinz's treatise on the subject, an excellent French translation of which, by M. E. Fiévet, was published in September last.*

A new way of manufacturing lead pipes with a lining of tin has been devised by M. J. Grant, Jr. The first step is the formation of a muff coated with tin on the inside. This is made in a horizontal mould, which is made to revolve with great rapidity, and is provided with a hollow axle through which the metals are introduced. The metals are fused in a crucible furnished with a stopcock or a clack valve opening into the hollow axle of the mould. One crucible will suffice, the lead being placed at the bottom and the tin on the top, the two being separated by an iron grating; or the tin may be melted in a separate crucible, provided with a valve, and placed above that in which the lead is melted. The object is, of course, to run the lead into the mould first, and to allow the tin to follow while the former metal is still liquid. A rapid movement of rotation keeps the two metals from mixing, while a perfect junction is formed as they solidify. When sufficiently cooled, the muff is transferred to the press, and the pipes are squeezed out in the usual way. Tin-lined pipes ought to command an extensive use for carrying soft waters and beer, and, no doubt, would be employed if they could be produced at a small advance on the price of lead piping. The plan of manufacture described here deserves attention, although it seems open to doubt whether

* *Documents concernant le Haut-Fourneau pour la Fabrication de la fonte de fer..* Traduits de l'Allemand avec approbation de l'Auteur, par E. Fievet.

the lining surface of tin would be perfectly continuous in the pipes. No doubt the adhesion of the two metals would be perfect.—*Mechanics' Magazine.*

Shellac Varnish.—The solution of shellac in borax does not answer well as a varnish, on account of the quantity of borax dissolved. But the solution in ammonia serves a good purpose. Puscher publishes some suggestions for making varnishes of various colors with it. Most of the insoluble earthy colors may be mixed with it. Sulphate of lime, however, is said to decompose the solution. Extract of logwood easily dissolves in it, so likewise does aniline green. We have long employed it to make an indelible ink, which is especially useful for laboratory labels, a mixture of lamp-black with the shellac solution remaining quite unaffected by acid vapors. The colored solutions are, in fact, available for many decorative purposes. The plain solution is made by macerating 3 parts of white shellac in 1 part of strong ammonia diluted with 6 or 8 parts of water. This mixture must be frequently shaken for 12 hours, after which the solution may be completed by the application of a gentle heat.—*Mining and Scientific Press.*

Metric Weights and Measures.—A report on the subject of the construction of primary international standards of metric weights and measures has been made this summer to the Imperial Academy of Sciences at St. Petersburgh, by a commission of members of the Academy appointed to consider the matter. The commission, which consisted of MM. Struve, Wild, and Jacobi, regard as an accomplished fact that all civilized nations have tacitly agreed to recognize the French metric system as affording for the future the advantages of a universal system of weights and measures, and to adopt the standards deposited at the Palais des Archives at Paris as the primary units of this system; but they observe that these are French standards, and all countries adopting the metric system are now compelled to apply to the French Government for permission to obtain copies. It is true that this permission is never withheld, but such copies are not compared directly with the standards of the Archives, but with duplicates at the Conservatoire Impérial des Arts et Métiers. The commission consider this course of proceeding unsatisfactory, and they propose that an international commission be nominated, composed of delegates from all civilized countries, for the construction and verification of primary international standards of measures of length, weight, and capacity, as the base upon which a universal system may be definitely established. They should also superintend the construction and verification of copies of these primary standards for the several countries.

The Channel Passage.—A highly interesting discussion took place at the Society of Engineers, at which the position given to the bridge project of M. Boutet, at the previous meeting, as reported in last week's Journal, was fully maintained—that it is undoubtedly the best of the numerous projects for establishing a continuous railway across the Channel. It was clearly explained that there is to be seen at Paris, and has been seen by some present, a model 66 ft. long, made to scale, which bore ten times the weight which would be required to be borne by the Channel Bridge, constructed with less than 1 ton of metal, and that this rested on two abutments of rough timber which were incapable of sustaining any great strain; and it was forcibly urged that the English engineers should make themselves acquainted with the theory by which such extraordinary results have been obtained, and study it as a novelty, instead of judging it by existing examples of bridges, and condemning it without understanding it. There is no doubt that if it does not widely differ from every other bridge yet constructed, it is nothing; and, therefore, existing formulas are not applicable to it. It seemed to be generally admitted that the existing spans of bridges were no criterion of what could be done, and several engineers mentioned instances of long spans which, compared with our ordinary experience, are surprising. Amongst others, it was stated that Mr. Ordish had designed a bridge with a span of $\frac{1}{2}$ mile, which Mr. Barlow checked and approved.—*Mining Journal.*

ON TUNGSTEN BESSEMER STEEL.

By CAPTAIN LEGUEN.

From "Comptes Kendus," through "Polyt. Journal."

I published some time ago a communication on my method of manufacturing tungsten Bessemer steel. This method consists in recarburizing Bessemer metal with a gray pig-iron, which originally was not of a superior quality, but was improved by the addition of tungsten or Wolfram metal. The steel thus produced was worked into rails, carriage springs, etc., and exhibited at the Paris Exposition of 1867.

I made lately the interesting experiment to alloy tungsten metal with spiegeleisen, instead of the ordinary gray pig-iron I had used before. The experiment was performed at the steel works of Terre-Noire (France,) whose Bessemer steel is used principally for rails. The pig-iron used at these works is manufactured from ores the greater part of which is imported from Mokta, near Bona, Algeria. The pig-iron is run from the blast-furnace directly into the Bessemer converter. The spiegeleisen is from St. Louis, and is remelted in a reverberatory furnace. My first operation was to combine a certain quantity of spiegeleisen with tungsten, by melting the iron in a cupola furnace, together with briquettes made from Wolfram ore, and reducing melters. I obtained thereby an alloy containing 9.21 per cent of tungsten metal.

A Bessemer charge was then made with 3,150 kilogrammes, or about 6000 lbs. of gray pig-iron taken directly from the blast-furnace. The process was conducted in the ordinary way, with the exception that the blowing was continued a little longer than usual, to obtain a very soft metal, and to see if the tungsten would be able to replace a part of the carbon in the steel without injuring the quality of the latter. A subsequent analysis showed that the steel made in this manner contained about half the amount of carbon then actually present in the steel fit for the manufacture of rails. The loss was ten per cent. The metal was recarburized with ten per cent. of the tungsten spiegeleisen mentioned above.

The metal produced contained .558 per cent. of tungsten. If no loss had occurred, the percentage would have been .837. The difference between these two numbers represents the amount of tungsten lost by oxidation in the reverberatory furnace and in the converter. When I made my previous experiments at the works at Imphy, this loss was more considerable, probably because the converter was turned up again for a short time after the addition of the recarburizer, which was not done at the Terre-Noire. It seems, therefore, probable that the loss of tungsten observed at the latter place originated exclusively in the reverberatory furnace, and that no such loss took place in the converter. The rolling of the tungsten steel ingots did not exhibit any peculiar feature. They were rolled into rails for the French Eastern Railroad. The rails, when finished, were laid into the track of the Strasbourg depot in Paris. They were also tested by a breaking strain and by concussion, as well as by forging and hardening. The engineer who was intrusted with this testing, reported to me on the result as follows:

"The tungsten steel rails tested at the depot of the Eastern Railroad were highly flexible and tough. The steel worked perfectly well in being hammered and jumped. In turning it off, chips of remarkable strength were obtained. To investigate into its capacity of hardening, several bars, 25 millim. square, were forged and hardened at a cherry-red heat. The grain in the fracture of the metal was, before this operation, large, white, bright, and somewhat hooky; after being hardened, it was very fine, gray, and showed a peculiar lustre like velvet. Any steel made at Terre-Noire by the ordinary method, and hardening so well, would be too brittle to be used for rails. But the tungsten Bessemer steel combines the highest degree of toughness with an eminent capacity for hardening."

These remarks show that tungsten steel can be at the same time soft, strong, and capable of being hardened. It would, therefore, be very useful for such parts of machinery as require to be hardened in some places, without losing their natural softness in others. The administration of

the French Eastern Railroad proposes to have the tungsten steel rails laid down into the track in places where they are subjected to a heavy wear, so as to acquire an exact knowledge of the comparative durability of these rails.

A great objection to the use of tungsten steel for rails is its price, which is considerably higher than that of ordinary Bessemer steel. Indeed, if the tungsten alloy had to be made from the tungsten metal in trade, which is produced by reducing tungstic acid, and costs 1½ fr. per gram, the steel would be much too dear to be used for rails. My method of making this alloy is, however, much cheaper, and can be more simplified yet by melting the spiegeleisen and the Wolfram briquettes in a cupola instead of a reverberatory furnace, and by running the alloy directly from the cupola into the converter, so as to avoid re-melting, and the loss of tungsten metal caused thereby. This loss would then not be higher than about ⅓ of the total tungsten contained in the Wolfram ore, and the cost of the rails would be higher than that of ordinary Bessemer rails by only 3.8 francs per 100 kil., or 1.44 francs per metre (24 cents gold per year). This increase of cost is not considerable, and is by far outweighed by the great advantages to be expected from the superiority of the quality.

ON THE NEED OF FURTHER EXPERIMENTS ON THE STRENGTH OF MATERIALS.

By MR. C. J. LIGHT.

From "The Mechanics' Magazine."

At a meeting of the Society of Engineers, held on Monday, the 15th inst., Mr. F. W. Bryant, President, in the chair, the following paper was read: All sound engineering practice must necessarily be based upon experimental research into the strength of the materials employed, whether these experiments are purely scientific, and conducted with the accuracy and precision necessary to qualify them for supplying data on which to base formulæ for general use, or of a rough and ready character hardly to be recognized as experiments. For even the most ordinary proportions of parts must originally have been based upon trials—very often upon failures. It is with the former class only that the author now proposes to deal, and to point out how far, in some very important branches, it has hitherto failed in answering its proposed end.

Two essentials of useful experiment are, that all action whatever that could interfere with the sole development of the strains to be investigated should be carefully eliminated, and that the apparatus used should possess the means of measuring the results with the utmost possible accuracy and delicacy. These points are essential, because, where they are neglected, it becomes difficult to say what are even the limits of error, much less what corrections have to be applied to the results obtained. If this be thought too much of a truism, it will be sufficient to refer to the practice, once almost universal, of applying tensile strains by hydraulic pressure, and measuring the force by means of a gauge connected directly with the press itself, when the friction of the cup leathers introduced an element of uncertainty which entirely vitiated the accuracy of the results. When the object of the experiments is to establish formulæ, it is clearly necessary that, besides the above-named conditions of the apparatus, the samples operated upon should be prepared with the utmost care and precision; but the author would suggest that at the same time samples should be prepared from identically the same materials, but under as nearly as possible the ordinary conditions of manufacture, so that a comparison of the two classes might afford data for determining what proportion of the theoretical strength might reasonably be calculated on in practice.

Of late years great numbers of experiments have no doubt been made, especially upon the resistance of iron to tensile and transverse strains; but they have been generally for private purposes, and have not been allowed to become known. A noteworthy exception, however, is the valuable series of experiments in wrought-iron and steel carried out by Mr. Kirkaldy

for Messrs. Napier, and so fully published, with their permission. Upon the questions of tensile and transverse strains, therefore, it may be said that our information is fairly complete; but on the highly important subject of compressive strains it is admitted on all hands that reliable data are sadly needed. In a recent communication to the Institution of Civil Engineers, a French authority, M. Gaudard, remarks that "the case of a pillar pressed upon its bases is very imperfectly understood. We are almost reduced to the application of formulæ purely empirical, which aim rather at conforming to observed facts than at explaining them." Whether the formulæ we have to rely upon deserve even the modified description of "conforming to observed facts," may well be doubted after a very slight examination and comparison.

It is surely a matter of great surprise that the best series of experiments into the strength of columns and struts dates as far back as the year 1840, when Mr. Eaton Hodgkinson tested a considerable number of small columns of various diameters and proportions with the express object of determining practical formulæ. Since then nothing further has been done in this direction, and the results at which he arrived are still the admitted basis of calculation for columns and struts. It might, therefore, have been expected that these results were so clear and satisfactory as to render further investigation unnecessary, which, however, is very far from being the case. For example, the well-known formula for long hollow columns with both ends fixed, that is, according to Hodgkinson, columns whose length exceeds 30 diameters, is:

$$W = 44.34 \frac{D^{3.55} - d^{3.55}}{L^{1.7}}$$

Where W = breaking weight in tons.
D = external diameter in inches.
d = internal diameter in inches.
L = length in feet.

On seeing so peculiar an index or exponent as 3.55 in a professedly empirical formula, it is natural for the student to suppose that the experiments rendered results at least very closely approximating to the index finally adopted. What, therefore, must be his surprise to find that in fact the indices obtained from the various experiments ranged from 3.922 to 3.412? (see the foot note page 333 of Mr. Hodgkinson's work). That is, if the external diameter be 12 in., the factor to be employed might range from $12^{3.922} = 17082$, according to one experiment; to $12^{3.412} = 4810$, according to another. The same remark applies to the factor $L^{1.7}$, as it appears that the index varied from 1.914 to 1.424.

In the sixth edition (1867) of Barlow on the Strength of Materials, edited by Mr. Humber, a short article on cast-iron columns has been inserted, which is an almost verbatim extract from Hodgkinson's work above referred to, and in which his formulæ are adopted as the best yet known, with a modification suggested by Mr. Hodgkinson, viz., taking the index of the diameter as 3.6 both for columns with fixed and with rounded ends. It is somewhat anomalous that, while adopting this modification, the effect of which is very considerable even in columns of moderate diameter, what may be almost called the affectation of extreme accuracy is retained in the constants of 44.3 for hollow and 44.16 for solid columns, where it is obvious that the decimal part exercises an influence upon the result perfectly insignificant as compared with that of the slightest change in the indices.

Another serious cause of uncertainty arises from the admittedly different kind of resistance offered by very long and very short columns, the one being principally a resistance to crushing and the other to flexure. Mr. Hodgkinson came to the conclusion that his formula for long columns could be adapted to short columns, at least for certain classes of iron, by means of the following expression:

Breaking weight of short column = W

$$= \frac{W \times C}{W + \frac{3}{4} C}$$

where C is the crushing force in lbs. belonging to the material employed $\times$ the sectional area of the column. As, however, C will in all ordinary cases be very large in proportion to W, the expression practically resolves itself into $w = \frac{3}{4} W$.

Now it is obvious that this is a most unsatisfactory solution, for it cannot be supposed that there is any point at which a sudden change of so considerable an extent takes place. Or, to bring the question to the test of an example, let it be supposed that the column whose break-

ing strength is sought is 30 ft. long, 12 in. external, and 12 in. internal diameter, is it to be classed as a long or a short column? In the former case, its ultimate strength would be, according to Hodgkinson's formula, 442 tons, in the latter 589. Nor, if it be admitted that there are two such distinct classes as long and short columns, is there any certainty as to the proportion at which the change occurs, other authorities placing it as low as 5 diameters in the case of cast-iron.

Leaving for a time the consideration of Hodgkinson's formula, the next that claims attention is that given by Professor Rankine:

$$W = \frac{8f}{1 + \frac{l^2}{c\,r^2}}$$

Where S = sectional area of a column, l = its length in inches, r the least radius of gyration of its cross section, f and c two coefficients depending upon the material, and appearing to have relation to its powers of resistance to compression and tension. It will be seen that no comparison can be made between this formula and Hodgkinson's, but it is evident that Rankine's bears a more purely theoretical character, and that it involves the fourth power of D, in which respect it agrees with that originally laid down by Euler, which Hodgkinson thought could only be reconciled with practical results by modifying the index as before noticed.

Besides these formulæ, there is also one quoted by Molesworth, though from what authority it was derived the author has been unable to ascertain. It is given on the 19th page of his Pocket-book, and called an "Approximate Rule for the Strength of Iron Struts," without any limitation as to the proportions between their length and diameter. For the case of hollow columns of cast-iron this rule gives:

$$W = S\ 36 \div 1 + \frac{l^2}{400\,D^2}$$

$$\text{or} = S\ \frac{36}{1 + \frac{l^2}{400\,D^2}}$$

Rankin's formula adapted to a similar case would be

$$W = S\ \frac{80{,}000}{1 + \frac{8\,l^2}{3{,}200\,D^2}} \qquad = S\ \frac{80{,}000}{1 + \frac{l^2}{400\,D^2}}$$

so that the forms are identical, while the difference of the coefficient is, in this case, but trifling, as Rankine's formula gives the value of W in lbs., and 80,000 lbs. = 35.715 tons. When, however, the material of the column is wrought-iron, the similarity of form continues; but the coefficients differ so greatly as to cause great discrepancy between the results—a discrepancy varying with the relations between the length and diameter. The same remarks apply to the formulæ given for columns of a hollow square and a cruciform section.

To assimilate the formulæ for wrought-iron to those of Rankine, they must be altered thus:

For cruciform, section, $16 \div 1 + \frac{l^2}{1{,}500\,D^2}$

For hollow square section, $16 \div 1 + \frac{l^2}{3{,}000\,D^2}$

For hollow cylinder section, $16 \div 1 + \frac{l^2}{4{,}500\,D^2}$

In order to show how great is the variance between the different formulæ, and therefore how uncertain any calculations of the strength of columns must be, it will now be desirable to give the results in a few practical instances. First, let the case be that of a cast-iron column 30 ft. long, 12 in. external and 10 in. internal diameter, with the ends flat. Hodgkinson's formula will give its breaking weight, if it be considered as a long column:

	TONS.
With index 3 55	442
With index 3.6 (said to be sufficiently near for practice)	505
If taken as *short* column	589
Or the same with index 3.6	631
According to Rankine's formula, taken as long column	380
According to the formula on page 19 of Molesworth	383

Which of these results, the extremes being as 5 to 3 very nearly, is to be taken as the true breaking weight of the column?

Again, take the case of a column, also of cast-iron, 30 ft. long, 24 in. external and 20 in. internal diameter, with the ends rounded, or, what is the same in effect, jointed. Hodgkinson's formula gives, with what he considers the true index for D, viz., 3.76:

	TONS.
Breaking weight	3,080
With the index 3.6 ("quite near enough for practice," let it be remembered!)	1,797
Or, if it be taken as a *short* column, which	

	TONS.
at the proportion of 15 diameters to the length, we have a right to do.....	4,107
Taken as a long column, by Rankine's formula.....	1,519
By formula page 19 Molesworth.....	955

In this case the extreme values obtained for W are to one another as 43 to 10, very nearly. How is it possible to arrive at any idea of the real strength of such column, which is yet one of very probable dimensions. If, however, wrought-iron be the material employed, the discrepancies become still more startling. Assuming the case of a similar column to the one first instanced, only in wrought-iron:

	TONS.
Hodgkinson would give.....	771
Rankine.....	463
Molesworth.....	170

The first result is based on the statement that the relative strengths in long columns of wrought and cast-iron are as 1745 to 1000—an hypothesis which must be entirely erroneous, for the ultimate crushing strength due to the area of this column, without any consideration of its liability to flexure, is only 586 tons (calculating at 38,000lbs. on the sq. in.).

The uncertain results of Mr. Hodgkinson's experiments must, there is no doubt, be chiefly attributed to the small size of the columns operated upon, and not to any want of skill or care on the part of the operator. The largest solid column tested was only 5 ft. long and 2 in. diameter, and in hollow columns the greatest length did not exceed 7 ft. 6 in. with a diameter of 3½ in. The more powerful means of testing now at the command of engineers would allow of experiments being made upon a much larger scale, and, it is reasonable to anticipate, with far more uniform results.

Before leaving this part of the subject it will be well to notice a remark of Mr. Hodgkinson ("Phil. Trans," 1840) respecting cases of imperfect casting in hollow columns, where the metal on one side was considerably thinner than on the other. He says: "It is gratifying to find that a matter which would seem to destroy all confidence in a pillar does not produce a great reduction in the strength." This apparent anomaly he explains by supposing that by some natural law the thinner side always takes up the compressive strain, and the thicker the tensile, and the instances that accidentally occurred among his experiments, certainly confirmed this supposition. This will be an important point for future observation.

In reference to wooden pillars or columns, it will be sufficient to remark that the best established formulæ give results which differ from each other in a similar manner to those for iron, though not to quite the same degree.

Enough has probably now been said to show how impossible it is, with our present information, to determine within anything but the roughest approximation what load any given column ought to bear before breaking. It is true that even if strict accuracy were attainable in this respect, there would yet remain the variations of material and workmanship to be allowed for, besides the important question of the factor of safety that should be adopted. But the author would urge that we ought not to be content until a theoretical basis has been established as certain and rational as that upon which calculations of transverse strains are now based.

Another class of experiments, much more readily to be made, and of a much simpler character, would yet be of great practical utility. Their object would be to determine the resistance to tranverse and compressive strains of wrought-iron L and T bars of various sections, and to deduce therefrom practical rules. It is very probable that ample materials already exist in private hands for compiling such information, and, if not, the necessary experiments could be easily and cheaply made. This is not a case requiring extreme accuracy, especially as it would be the actual full-size bars that would be operated upon; but every engineer ought to have the means of determining at a glance what load any given bar will probably bear. Such tables would be the means of saving many a ton of metal in roofs and flooring, etc., and would afford the designer an assurance of the efficiency of his structure, which he cannot at present be said to have.

The next series of experiments to the need of which the author desires to call the attention of the Society would require very great care and skill, both in arranging and in carrying out. They refer to the true proportioning of the eyes of links. It is now many years since attention was first directed to the necessity for provid-

ing, not only a sufficient shearing area in the bolts or pins securing links, tie rods, etc., but also a sufficient bearing area of the link or tie itself upon the bolt—a point which appears to have been overlooked, at least in civil engineering, until the rapidly extending use of iron roofs, and the desire to reduce every part to the slightest possible form, brought it into prominence. And even now there is great difference of opinion as to the extent of such bearing area, some authorities contending that the crushing strain so induced ought not to be allowed to exceed (for wrought-iron) 5 tons to an inch, while others would extend the limit to 7 or 8 tons. The correct proportions for the eyes of links whose thickness is small in proportion to their breadth, as in those of bridges, still present a vexed question; and it is not easy to determine how far they are affected by the unavoidable irregularities of manufacture.

Experiments appear to show that the proportions at present adopted in the best practice, though greatly modified from those at first used, are even yet insufficient to secure the fracture of the link through the body in preference to the eye. The author submits that it would be highly desirable to arrange and carry out a series of experiments on links of graduated cross sections, from the thin link, as employed in the lower members of bridge girders, to one of a square section, with a view to determine the proper proportions for the eyes under these varying conditions. It is, however, quite probable that a large amount of information already exists suitable for such determination if it could only be brought together under such conditions as to permit of a fair comparison of results.

Upon the strength of timber as a material of construction there have been made so great a number of experiments that it may be doubted whether fresh ones would add much to our knowledge of the subject. It may be remarked, however, that the greater part of these, also, are open to the objection before referred to, of having been made upon exceedingly small pieces. It is also true that with timber so very much depends upon the age, the growth, and the place of growth of the tree, that it can never be expected that calculations for this material can be brought within the same limits of accuracy which may be fairly looked for in the case of iron.

Further experiments are probably desirable on the strength of combinations of timber and iron, such as trussed beams, keeping in view the consideration that the timber must necessarily yield to a considerable extent before any appreciable strain is brought upon the iron tie. This objection is of much greater force in the case of the flitch girder, in which the timber ought only to be looked upon as giving lateral stiffness to the iron plate.

In reference to the important question of the strengths of stone, brick, cement, and artificial stone, there is still room for a well-arranged series of experiments, especially if made upon much larger samples than those which have hitherto been operated upon. Another interesting subject for fuller experiment is that of glass, as laid in sashes both of wood and iron. In the latter case, observations should be made under varying temperatures. The object of this paper has been, not so much to call the attention of engineers to a want which the author is well aware is already known and admitted, as to elicit from all who take an interest in the subject such information as they can contribute to the common fund, and such suggestions as may lead to a practicable remedy for a state of things which cannot be considered creditable to the present position of engineering science.

Some interesting experiments have taken place at Perm, Russia, with a new 20-in. gun, cast in the foundry of that town. The trials made with this gun, under the direction of Major-General Pestitch, commandant of the Cronstadt artillery, are described in the official reports as having been very successful, and more satisfactory in their results than had been the case with American guns of the same calibre. The gun was fired 314 times; the projectile weighs 10 cwt., and the charge of powder required for each shot was 130 lbs. The weight of the gun is about 50 tons, the recoil 7 ft., the initial velocity of the projectile 1,120 ft. per second, and the percussion force, at a distance of 50 ft., about 10,000 tons. The official papers say this is "the most powerful gun in Europe."

THOMSON'S ROAD STEAMERS IN PARIS.—Within the last few days one of Mr. R. W. Thomson's road steamers, with india-rubber tyres, has been running through the streets of Paris, dragging behind it a heavy Versailles omnibus, with 50 passengers. On the report of the French Government enginers, leave has been granted to the road steamer to ply over two routes, several miles in length, and including some busy parts of Paris. The engineers report it more handy and manageable than horses, and in no way dangerous to the public. The huge india-rubber tyres save the machinery from jolting and the road from ruts. The speed is that of a fast omnibus; it went up the paved street beside the Trocadero, of which the gradients are 1 in 11, and even 1 in 9, without the least difficulty, and came down again without any brake. In a wet grass field it was curious to observe how little the wheels sank into the saturated soil; in fact, it obliterated, on retracing its circle, the deep ruts of the omnibus wheels. This circumstance has drawn the attention of artillery officers present at the experiment, suggesting to them an inquiry whether the system might not be advantageously applied to military transport in campaigning.—*Engineering.*

THE DETROIT RIVER TUNNEL.—The experimental borings for the projected tunnel under the river at this point have now virtually been concluded. The earth was found to be more and more favorable at each successive trial. Occasionally soft "streaks" were found near the surface, but a few feet down a hard tenacious formation of blue clay was invariably reached, which presents a very uniform appearance. The greatest depth of water is found about 1200 ft. from the shore, where it is about 48 ft., whence it gradually shoals to a depth of about 25 ft., upon this side. The depth above named (48 ft.) may be considered the maximum, except so far as it is varied by holes. The depth of the borings is 98 ft. from the surface. The soundings of the river vary somewhat from those which have been made under the auspices of Government, but this is very natural in view of the difficulty of taking accurate soundings with the lead in a current of three and a half miles an hour. The figures now arrived at are strictly accurate, being taken with an iron rod confined in a tube, which tube is stayed in such a manner as to prevent swaying even in the remotest degree.

OSCILLATION OF RAILWAY TRAINS.—Sir Charles Fox states his opinion that the oscillation of railway trains, more especially at high velocities, producing what is ordinarily called "gauge concussion," is caused in a very great measure by the use of wheels the tyres of which are portions of cones instead of cylinders. It is well known to engineers that the tyres of railway wheels are generally coned to an intonation of 1 in 20. It is considered that these were first introduced by George Stephenson, in the expectation of facilitating the passage of vehicles round curves by their adapting themselves, through their various diameters, to the different lengths of the two rails on which they were running. This, however, is not the case in practice. No advantage is found to arise in the use of conical wheels in passing round curves, and as much evil results therefrom on straight lines, Sir Charles has constructed upward of 250 miles of railway abroad, in the rolling stock of which he has departed from the usual form of wheel, and has used only cylindrical ones, and he has been gratified with the satisfactory reports of the steadiness of trains supplied with them.—*Engineering and Mining Journal.*

BRITISH MINING STATISTICS.—Last year 296,660 persons were employed in coal mining in England and Wales, and 59,160 in Scotland. The quantity of coal raised in Great Britain was 104,566,959 tons. There were 860 separate fatal accidents, and 1,011 lives lost, the proportion of persons employed for separate fatal accidents being 403, and 343 employed to every life lost. Every 103,429 tons of coal raised appears to have cost a life. These operations were carried on in 3,262 collieries. There were also 69 lives lost in iron-stone mines.

A FINLAND vessel has conveyed to St. Petersburg two enormous blocks of stone from the banks of Lake Lodoga, each weighing 72,000 lbs, to be used for the pedestal of the statue of Catherine II.

THE CONTRACTION OR SHRINKING OF TIMBER.

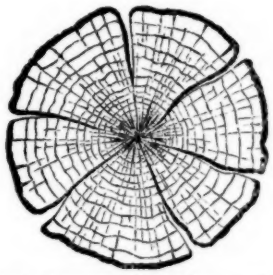
From "The Builder."

In a lecture on Applied Mechanics delivered by Mr. John Anderson, C. E., at the Society of Arts, some information was given on the contraction of timber, which calls for transference to our paper:—

Notwithstanding the extent to which timber is used in the mechanical arts, it is singular that the mechanical law by which the contraction or shrinking of wood is governed is too much disregarded in practical operations. I am not aware of any book that explains the subject fully, and have met with only one individual who has thoroughly studied it as a philosophical question and reduced it into the unerring every-day practice of his own works. The wretched state of the floors, doors, and shutters in many of the London houses, too plainly gives ample and complete evidence of our persistent disobedience of the law, and the only hopeful consolation is that as we do not go unpunished, the penalty inflicted may in time lead to improvement.

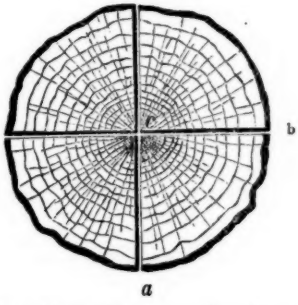
An examination of the end section of any exogenous tree, such as the beech or oak, will show the general arrangement of its structure. It consists of a mass of longitudinal fibrous tubes arranged in irregular circles that are bound together by means of radical strings or shoots, which have been variously named. These are the "silver grains" of the carpenter, or the medullary rays of the botanist, and are in reality the same as end wood, and have to be considered as such, just as much so as the longitudinal woody fibre, in order to understand its action. From this it will be seen that the lateral contraction or collapsing of the longitudinal porous or tubular part of the structure cannot take place without first crushing the medullary rays; hence the effect of the shrinking finds relief by splitting in another direction, namely, in radial lines from the centre, parallel with the medullary rays, thereby enabling the tree to maintain its full diameter, as shown in Fig. 1. If the entire mass of tubular fibre composing the tree were to contract bodily, then the medullary rays would of necessity have to be crushed in the radial direction to enable it to take place, and the timber would thus be as much injured in proportion as would be the case in crushing the wood in the longitudinal direction. If such an oak or beech tree

Fig. 1.



is cut into four quarters, by passing the saw twice through the centre at right angles, before the contracting and splitting have commenced, the lines *a*, *c*, and *c*, *b*, in Fig. 2 would be of the same length,

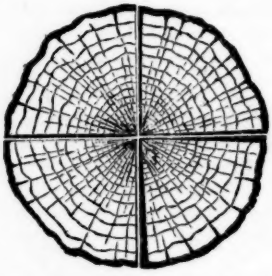
Fig. 2.



and at right angles to each other, or, in the tecnical language of the workshop, they would be square; but, after being stored in a dry place, say for a year, it would then be seen that a great change had taken place both in the form and in some of the dimensions; the lines *c*, *a*, and *c*, *b*, would be the same length as before, but it would have contracted from *a* to *b* very considerably, and the two lines *c*, *a*, and *c*, *b*, would not be at right angles to each other, by the portion here shown in black in Fig 3. The medullary rays are thus brought closer by the collapsing of the vertical fibre. But, supposing that 6 parallel saw-cuts are passed through the tree so as to form it into seven planks, as

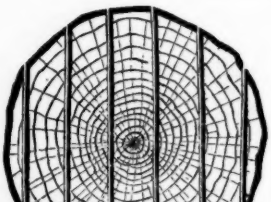
shown in Fig. 4, let us see what would be the behavior of the several planks. Take the centre plank first. After due seasoning and contracting, it would then be

FIG. 3.



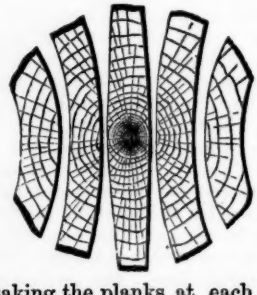
found that the middle of the board would still retain the original thickness, from the resistance of the medullary rays, while it would be gradually reduced in thickness

FIG. 4.



towards the edges for want of support, and the entire breadth of the plank would be the same as it was at first, for the foregoing reasons, and as shown in Fig. 5.

FIG. 5.



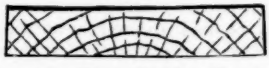
Then, taking the planks at each side of the centre, by the same law their change and behavior would be quite different; they would still retain their original thickness at the centre, but would be a little reduced on each edge throughout, but the side next to the heart of the tree would be pulled round or partly cylindrical, while the outside would be the reverse, or hollow, and the plank would be considerably narrower throughout its entire length, more especially on the face of the hollow side, all due to the want of support. Selecting the next two planks, they would be found to have lost none of their thickness at the centre, and very little of their thickness at the edges, but very much of their breadth as planks, and would be curved round on the heart side and made hollow on the outside. Supposing some of these planks to be cut up into squares when in the green state, the shape that these squares would assume, after a period of seasoning, would entirely depend on the part of the tree to which they belonged; the greatest alteration would be parallel with the medullary rays. Thus, if the square was near the outside, the effect would be as shown in Fig. 6, namely, to contract in the direction from *a* to *b*, and after a year or two it would be as seen in Fig. 7, the distance between *c* and *a*

FIG. 6.

FIG. 7.

being nearly the same as they were before, but the other two are brought by the amount of their contraction closer together. By understanding this natural law, it is comparatively easy to know the future behavior of a board or plank by carefully examining the end wood, in order to ascertain the part of the log from which it has been cut, as the angle of the ring growths and the medullary rays will show thus, as in Fig.8. If a plank has this ap-

FIG. 8.



pearance it will evidently show to have been cut from the outside, and for many years it will gradually shrink all to the breadth, while the next plank, shown in Fig. 9, clearly points close to the centre

or heart of the tree, where it will not shrink to the breadth, but to a varying thickness, with the full dimensions in the middle, but tapering to the edges, and the planks on the right and left will give a mean, but with the centre sides curved round, and the outside still more hollow.

Fig. 9.

The foregoing remarks apply more especially to the stronger exogenous woods, such as beech, oak, and the stronger home firs. The softer woods, such as yellow pine, are governed by the same law; but in virtue of their softness another law comes into force, which to some degree affects their behavior, as the contracting power of the tubular wood has sufficient strength to crush the softer medullary rays to some extent, and hence the primary law is so far modified. But even with the softer woods, such as are commonly used in the construction of houses, if the law is carefully obeyed, the greater part of the shrinking, which we are all too familiar with, would be obviated, as the following anecdote will serve to show:—It was resolved to build four houses, all of the best class, but one of the four to be pre-eminently good, as the future residence of the proprietor. The timber was purchased for the entire lot, and the best portions were selected for house No. 1, but by one who did not know the law, and to make certain of success this portion of the wood had an extra 12 months' seasoning after it was cut up. The remainder of the wood was then handed over to a contractor for the other three houses, who had an intelligent young foreman, who knew the structure of wood, as well as how to obey the law, and who, therefore, had the wood for the three houses cut up in accordance therewith. The fourth house was built the following year by another man; but long before 10 years had passed, and to the great surprise and annoyance of the proprietor, it was found that his extra good house, No. 1, had gone in the usual manner, while the other 3 houses were without a shrinkage from top to bottom. As Solomon says, "Wisdom is profitable to direct."

A similar want of correct knowledge of the natural figure and properties of the structure of wood, such as the oak, is constantly shown by the imperfect painting to resemble that wood, as exhibited on the doors and shutters of many of the houses of this metropolis. If we cannot afford to have genuine wainscot doors, as in France, but yet desire to have an imitation, it would surely be worth the trouble to have a block cut from the quarter of an oak tree, and to have each of its six sides planed and polished, in order to make plain their several features. The house-painter would then see what nature really is, and thus save us from the ridicule of other nations, when we mix up "silver grains" and all the other natural features upon one side of a board or panel.

At the ironworks of Aulnoye, in Belgium, the slag is utilized by casting it into slabs for paving, garden rollers, and other things. For the former purpose, moulds are excavated in the ground around the furnaces, of sufficient extent to receive all the slag running from them, and trenches are cut to carry the liquid slag. The only precaution to be taken, we are told, is to cause the slag to run under the vitreous layer, which solidifies at the beginning of the running, and to keep the moulds warm, so that the slabs may not solidify too rapidly. For this purpose it is often necessary to cover up the trenches and moulds with cinders and small coal. The cooling should indeed, be made to occupy several days; and, in that case, there will be found under the vitreous crust a compact homogeneous slab, in appearance very much resembling natural porphyry. The masses are often divided by fissures, but the pieces can be dressed and trimmed into blocks for paving. To obtain sound rollers, it is necessary to take especial care in the cooling and solidifying. It is hardly necessary to add that the slags employed for these purposes must be solid and lasting, and not at all brittle.—*Mechanics' Magazine.*

To prevent accidents to workmen in wells, a safety cradle, consisting of a framework of wood with a rope matting or basket, to be fixed a little under water, is proposed. This seems an excellent suggestion, and well calculated to save many lives.

WHITWORTH METAL.

From "The Railway Times."

It is well known to mechanics that Mr. Whitworth has been long engaged in testing a new process of making and casting iron and steel, which he has invented with the view of getting rid of all those accidents which arise from the air bubbles found more or less in all iron castings, and not removable by any amount of hammering. Mr. Whitworth has now perfected a mode of casting metal which renders it so homogeneous that it resists any given forces which can be brought to bear upon it. The following notice which recently appeared in the London "Times," gives an interesting account of the application of the Whitworth metal to ordnance. The notice is written by an officer of the Royal Artillery, thoroughly acquainted with the subject:

"Mr. Whitworth has long been known as a mechanician of the highest order To him is due the accuracy with which machinery may now be made to turn out work almost perfect in its beauty and precision of dimensions. When once the transference of circular into direct or eccentric motion, and the converse, was achieved, it was easy to devise a thousand means of carrying the discovery into practice, and, theoretically, of producing any, even the most delicate forms. But the main difficulty had still to be surmounted. The machines themselves were imperfect in dimensions. There was no such thing as an exact plane in existence, much less an exact sphere or cylinder or cone. Every part of every machine was really rough and uneven in surface, however precise it might appear to the naked eye, and it is clear that wheels of imperfect roundness, turned by equally imperfect shafts, working in imperfect beds, could never turn out perfect productions. The defects continued to reproduce themselves, for the parts of new machines were made by the old ones. A beginning had to be made somewhere. Mr. Whitworth set to work to make plane surfaces of mathematical accuracy. First manufacturing three flat pieces of hard metal as exact as was possible by the ordinary means, he then rubbed two of their surfaces together till there remained no perceptible friction. He then took the third and worked it on to the two others, continuing the process till the three were so equal that, if any two of them were laid one upon the other, they touched nowhere, the upper one floating on an extremely thin film of air between them, without friction. If the edge of the upper one was pressed on the lower surface and pushed along it, followed by the body itself, there was no air between, and the two adhered together, held fast by the pressure of the atmosphere above and below. Here was the germ from which sprang exact spheres, cylinders and wheels, the parts of machines which could be relied upon. Henceforward there was no limit to the preciseness of the productions, except the wearing of tools or of the machinery itself. But a finer test of the work was required than any then in existence; so Mr. Whitworth designed a measuring instrument, capable of marking faults for correction even if they did not exceed the millionth of an inch. So the work produced and the parts of the machines could be rigorously tried, and many a new flight could be taken in the region of mechanics.

"When the demand came for small arms and cannon of longer range and closer shooting, Mr. Whitworth carried out a series of experiments for the Government, laid down what he considered to be the laws governing the rifling of barrels and the shape of projectiles, and produced a rifle which attained results hitherto unknown. He proceeded to apply the same principles to artillery, and competed with Armstrong for the position of first artillerist in the world. But his rival had already, not designed, but built a large number of guns fulfilling in their construction the demands of practical soldiers, as well as those of scientific artillerists. The ground was already occupied, and when it was found that neither inventor could claim any decided superiority over his antagonist, the strong practical objection to complication of guns and ammunition, by the adoption of two complete systems side by side, was, very properly, allowed to weigh against Mr. Whitworth. If the public service be the first consideration, many an ingenious inventor may find that

there is no room for his works, though he may well deserve a handsome acknowledgment in one shape or another.

"Since the days of the Armstrong and Whitworth Committee, Mr. Whitworth has never dropped the subject of artillery. It was not enough for him to be acknowledged as the first machinist in England, he must also be accepted as in the front rank of artillerists—a desire which he shares in common with many others. Such an end is only to be attained by the manufacture of reliable heavy rifled guns, such as 300, 400, and 500 pounders, or pieces of even higher calibre, and Mr. Whitworth was long unsuccessful in producing anything higher than a 7-in. gun. His system of gunnery is acknowledged by himself to be very severe upon the piece from which his long projectiles are fired, and we have more than once heard from his own lips that he sought in vain for a material which could be relied upon, and produced in sufficient quantities. He adopted a mild steel as the metal theoretically most adapted to withstand both strain and wear, but he found, as all makers of steel guns have found, that the greatest care was unavailing to produce trustworthy steel tubes in large quantities and of large sizes. Many a fair-seeming piece of a gun would stand steady strains carefully, but crack when the sudden shock of fired gunpowder occurred within it. So much material could not be wasted without increasing the cost of that which was sound, nor could guns be produced rapidly or in large quantities. The English Government would hardly accept 9-in. guns costing £3,200 each, except for purposes of experiment, when pieces of equal calibre could be bought from Armstrong for considerably less than half the price, or manufactured in the Royal Arsenal, on Fraser's still cheaper system, for little over a fourth. Two such guns were purchased before the late Conservative Government came into office, and their shooting was, what Whitworth shooting has always been, extremely good. The experiments with them seem to hang fire, chiefly, we believe, on account of some lack of harmony between Mr. Whitworth's idea of fair experiments and those of the Ordnance Department in the War Office.

"The subject would have been of little importance, but for a most interesting and valuable attempt of Mr. Whitworth to solve the one great problem of artillerists, by producing guns at once strong, cheap, and capable of being manufactured in large quantities. In spite of all researches, the reasons for the peculiar qualities of steel are still doubtful, but the most important and undesirable quality, that which breaks the hearts of gunners, is the uncertainty of the metal. Of two tubes manufactured at the same place, about the same time, by the same workman, one may stand 1,000 rounds, and the other burst destructively at the first or fiftieth round, sometimes without the slightest warning. One reason given is that bubbles of gas formed in the molten steel before it is set are retained by the thickening fluid, and perpetuated as flaws in the ingot, no matter how severe a hammering it may have had. Mr. Whitworth claims to have succeeded in getting rid of these gas or air bubbles entirely, by the application of immense pressure to the mass of molten metal while cooling. He has four qualities of this steel, or "Whitworth Metal," as he calls it. They are known as yellow (having most carbon,) blue, brown, and red, the red being the most ductile. He has tried many experiments on a small scale, and considers himself to be justified in declaring that he will now be able to make heavy guns perfectly trustworthy at a price of about £120 a ton, or one-fifth higher than Sir W. Armstrong's present prices, and rather more than half his own old ones. A 9-in. gun would cost £1,800, but then its projectiles would be heavier, and its power greater than its rival of the service pattern. Mr. Whitworth is pre-eminently an advocate of small bores in guns as well as rifles, being ready to sacrifice many practical advantages for good shooting. He now asserts that he throws to the winds all fear of his guns bursting. Instead of seeking for powder of less severity, his only wish is to find means of igniting it more rapidly, and he is making preparations for the construction of 27-ton guns, or even pieces weighing over 43 tons.

"It may be that Mr. Whitworth has achieved a task which would certainly lead to the adoption of his metal for the inner tubes, at least, of all guns, whatever might be their system of shooting; but the experience of all practical artillerists denies them permission to accept experiments on a small scale, as applicable to

heavy guns, in which the force of the explosion is vastly multiplied, possibly even altered in its mode of action. The Government possesses two heavy Whitworth guns, but they are not made of the new metal, except in very small proportion applied to the exterior of the piece. They may be very useful to test ammunition, system of rifling, and so on, but their lasting qualities will prove nothing as to strength of the new metal for guns, because they are made of the old metal. We understand that the superintendent of the gun factories applied to Mr. Whitworth for inner barrels, but was answered that the whole system or nothing must be taken. This seems a little obstructive; but here is a man of reputation asserting that he has the power of producing metal of extraordinary strength, and that he has actually commenced to make two 11-in. guns calculated to fire shells of 960 lbs. If he will not allow his material to be tried as a part of the Government ordnance, we cannot but think that it would be worth while to order one gun from him, embodying his newest ideas, and test it in everyway without competition, for it seems that in this way alone can the authorities arrive at truth regarding the strength of the Whitworth metal as applied to heavy guns. It should be distinctly understood that Mr. Whitworth's system of charges and projectiles is acknowledged by him to be extremely dangerous to the endurance of the pieces of ordnance themselves, and must be rejected unless he can find material to bear the severe strain put upon it. If the new metal fails, his case falls to the ground; but it is surely worth a trial.

"There is, however, another experiment possible to be carried out with the two costly guns now in the hands of the authorities. Mr. Whitworth insists that flat-headed shot or shells, very long, and therefore containing a large bursting charge, are the proper projectiles to fire at iron plates, especially when the target stands obliquely to the line of fire. We have inspected certain plates containing holes pierced or punched by flat-headed projectiles fired from the Whiteworth 1¾-in. gun of 7 cwt. A plate of equal thickness with the shell was completely pierced at an angle of 45°, and with a charge of 10 oz. At an angle of 65° the shell did not pass through, but made a ragged hole. At right angles it passed easily through a 2½-in. plate. A service gun of equal weight would have a calibre of 3 in., and be capable of piercing at least the 2½-in. plate directly, probably a 3-in. plate. But it is not with these tiny pieces of ordnance that artillerists' attention is now chiefly occupied, at least out of England. The great point is to make guns and projectiles that will pierce iron-clad ships at all sorts of angles. The rough-and-ready rule with our service gun is, that a shot or shell will pass through an iron plate somewhat thicker than its own diameter; a 9-in. projectile through more than a 9-in. plate, etc. But Mr. Whitworth contracts the diameters of his projectiles for the same weight both of gun and ammunition. He makes his shells long and narrow, so the rough rule has no application to them. We should very much like to see what target would be pierced by the Whitworth guns with Whitworth flat-fronted projectiles, and at what angle. The experiment is surely worth the small sum of money it would cost. It is of no use to point to experiments made with 2-in. guns. All working artillerists have been disappointed, over and over again, at the difficulty of getting big guns to do as well, in proportion to their bulk, as small ones. But there are the big guns; why not try the long, flat-fronted projectiles? When the question comes before Parliament it is sure to be made as foggy as possible. Let us try for once to state it clearly.

"Whitworth's system of artillery consists essentially in small-bore guns with long projectiles. The twist of the rifling must be rapid, because otherwise the long projectiles would turn over. All this involves a great strain upon the interior of the gun. Until now he has not succeeded in making heavy guns to stand this strain, except in small numbers, at a prohibitory price. He now asserts that he has found the material he has so long sought; but there is, as yet, no heavy gun in existence made of this material. We say, let him make one, and let it be tried. Then, there is that other question of his shells, which has nothing to do with the gun question, and may be settled by firing some projectile out of the costly pieces now in possession of the Government. If the shells succeed, it will be interesting to know whether Mr. Whitworth can really make guns at a reasonable price

capable of firing them. Then comes the last question, perhaps more difficult still to answer: Where can such guns be placed without involving such a complication of ammunition and stores as would be detrimental to the public service? We hold that Mr. Whitworth has made out a case for experiment."

THE COMBUSTION OF GUNPOWDER.

From "The Engineer."

The questions, What are the combustions of gunpowder? and are these constant for all pressures under which the powder may be exploded? have been investigated by two observers, who arrived at somewhat discordant conclusions. Craig maintained that with varying pressures varied products were formed. Von Karolyi, on the other hand, believed the composition of the solid residue to be but slightly dependent on the manner of the explosion. The subject has recently been reconsidered in Germany by Federow, a lieutenant of artillery, the results of whose experiments confirm the view held by Craig.

He prepared the residue by firing powder in a pistol attached to a glass tube 4 ft. in length, and likewise by using a brass cannon, a 9-pounder, each charge of which amounted to 3 lbs. of Russian powder. The powder and the charcoal it contained had the following percentage composition:

Gunpowder.		Charcoal of Gunpowder	
Saltpetre....	74.175	Carbon.....	72.5
Charcoal.....	14.835	Hydrogen.....	2.9
Sulphur.....	9.89	Oxygen.....	22.3
Water.....	1.1	Ash.....	2.3
	100.000		100.0

The residue, after explosion, was dissolved in water and separated from the charcoal and sulphur by filtration; the filtrate was digested for several days with carbonate of cadmium and repeatedly shaken. From the amount of sulphide of cadmium formed, the quantity of sulphide of potassium in the specimen was calculated. Of the other potash salts the hyposulphite was determined by precipitation with nitrate of silver, the sulphocyanide by Bunsen's color test, the carbonate by precipitation with chloride of manganese, and ignition in the form of $Mn_3 o_4$, and the unchanged nitrate from the loss.

Below are the names of a number of analyses made on this principle:

Percentage Composition of Dried Residue.

	Blank charge of 0.75 grammes.		Blank charge of 1.5 grammes.		Cannon charge 3 lbs.	
Sulphate potash.....	48.25	47.61	40.83	43.28	15.00	15.15
Carbonate potash.....	23.44	21.13	30.96	31.9	37.00	36.2
Hyposulphite potash.....	16 53	17.03	19.32	17.74	38.28	7 44
Nitrate potash.....	5.81	5.66	2.79	1.73	..	....
Sulphide potassium.....	0.97	0.51	2.49	1 67	8.18	39.55
Sulphocyanide potassium	0.54	0.51	0.56	0.50	0.33	0.33
Sulphur.....	0.38 }	4.49	3.05	0.22	0.00	0.00
Charcoal.....	4.08 }			2.0	....	1.02
Sand, oxide copper, etc..	....	....	....	....	0.82	0.12
Carbonate ammonia.....	Traces.		Traces.		....	....

These numbers unquestionably show that by increasing the charge, the decomposition of the powder becomes the more complete. The greater the pressure during explosion the less the amount of unchanged gunpowder found in the residue, and the richer the latter is in sulphide of potassium and corbonate of potash, while its proportion of sulphate of potash is in like manner diminished. With increased pressure the yield of hyposulphite likewise falls.

Whatever prolongs the combustion operates like an increase of pressure. Such a condition can be brought about by mixing the powder with some fatty substance. A blank charge of 1.5 grammes of a mixture of 100 parts meal powder and 0.5 of stearic acid, left a residue composed of sulphate of potash, 31.57; hyposulphite, 22.25; carbon, 39.09; sulphide, 2.01; sulphocyanide, 0.74; charcoal, 4.02; sulphur, 0.32. The amount of hyposulphite had therefore increased, and that of sulphate decreased.

In an experiment with the cannon, 100 parts of anhydrous gunpowder left 49.61 per cent. of solid residue; whence it may be calculated that one gramme of material yielded in this case 0.039 grammes of aqueous vapor, and 258.7 cub. cent. of gases, made up of 82.6 cub. cent. of nitrogen, 162.1 cub. cent. of carbonic acid, and 14.0 cub. cent. of sulphurous acid and oxygen. Almost all the carbon,

therefore, is converted into carbonic acid, and by combustion under pressure the temperature will be higher than in cases where small quantities are exploded under ordinary conditions.

Federow considers his experiments demand another interpretation of the phenomena attending the firing of gunpowder than those proposed by Bunsen and Schischkoff, and proposes the following scheme as the more correct one :

When powder is fired, several successive reactions take place. The sulphur ignites, forming sulphate of potash. The excess of oxygen converts a part of the charcoal into carbonic acid, which escapes with the nitrogen, whilst the remaining carbon reduces the sulphate to carbonate, hyposulphite and carbonic acid (or carbonic oxide).

$$\text{I. } KNO_6+S+C=KSO_4+N+CO_2.$$
$$\text{II. } 2KSO_4+2C=KS_2O_3+KCO_3+CO_2.$$

If the powder does not contain the sulphur required by the normal composition (KNO_6+S+3C), as is the case with the Russian gunpowder, and that used by Bunsen and Schischkoff, there is produced in Reaction I. carbonate, in addition to sulphate. During explosions in open tubes Reactions I. and II. only occur. If the combustion take place under pressure, however, the excess of carbon produces a further effect by causing reduction:

$$\text{III. } 2KS_2O_3+3C=3CO_2+2KS+2S ;$$

and the sulphur thus set free can act on the carbonate in Reaction II. The hyposulphite, moreover, it is known, cannot withstand a high temperature, and the sulphur will affect the carbonate according to the following equation:

$$\text{IV. } 4KCO_3+4S=KSO_4+3KS+4CO_2.$$

And here, again, by secondary reactions, sulphocyanide is produced.

These views Federow confirmed by experiment. It follows from the composition of the powder employed, that according to Equation I., 100 parts of material will at the first instant produce 67.9 parts of residue, consisting of 54.4 of sulphate, 8.1 of carbonate, and 5.4 of charcoal, or in percentages, 80 sulphate, 12 carbonate, and 8 charcoal. But in the fifth experiment quoted, 15 per cent. of sulphate were found, and 65 per cent. of this salt had therefore been decomposed. Now from Equation II.,

$$2KSO_4 : KCO_3 :: 174 : 69 ;$$

65 parts of sulphate, therefore, correspond with 25.8 of carbonate. Consequently the total amount of carbonate should be 25.8+12.0=37.8, and the direct result of the experiment gave the number 37.0. In like manner are the other analyses of the powder residues capable of explanation.

FILTRATION OF WATER.

From "The Building News."

The old-fashioned way of filtering water by introducing it underneath the filtering materials, and, by the pressure of an external head, forcing it upwards through gravel and sand, has been given up. All engineers now adopt the system first introduced about 30 years ago by the late Mr. James Simpson at the Chelsea Water Works, when those works were situated at Thames Bank—viz., the downward, instead of the upward system.

The objection to the upward system of filtration is that the mud, lodging in the spaces provided for it underneath the filtering materials, cannot be got at for removal conveniently, and mixing itself amongst the gravel and coarser sand, it fouls them, and spoils the action of the bed.

At first sight, and without taking into consideration these objections, it seems an attractive feature of this method that the water bubbles up through the sand bed very much after the manner of natural springs—the dirty water is hidden from sight and only the clear water appears ; whereas, in the downward system, the dirty water only appears, and the pure water passes out of sight. In real efficiency, however, the latter method is much to be preferred.

The downward system has for its object the arrest on the surface of the sand, of all matter in suspension in the water, where it can be easily got at for removal when necessary, and being so arrested on the surface it never gets into or amongst the gravel or the coarser sand. These

materials, therefore, never require removal. All that is necessary is to scrape off from the surface of the sand the mud there deposited, as often as may be necessary, the period varying with the state of the water before filtration. The Thames water, before the works of the London Water Works companies were removed above the tideway, was constantly turbid, and in those by-gone days the filter-beds required to be shut off and cleaned at very short periods of time ; but now that the water is taken above the tideway, although more sewage is poured into the river than formerly, the water is seldom turbid, except when the river is in a state of flood ; and the periods of shutting off the filter-beds for the purpose of removing the mud deposited on the surface of the sand are greatly extended.

A rough preliminary process of filtration, or straining, is often effected by vertical filters or strainers ; sometimes by a thickness of two or three feet of fine gravel contained between walls of brickwork with open joints, or more often by copper wire gauze held in wooden frames, and removable bodily for cleansing; while, when the gravel within walls requires cleansing, it has to be removed by the usual process of excavation. The copper wire gauze in the straining frames is usually of the fineness of about sixty strands to the inch, and is protected from injury by a coarser kind of iron wire netting of about 1½-in. mesh. The frames are held in their upright position in grooved standards or pillars of either cast-iron or masonry. It is desirable that the water should pass very slowly through the strainers, and without force, in order to prevent the flow of water carrying with it the solid particles in suspension in the water; indeed, slowness of motion is an essential feature in all processes of filtration.

In constructing a filter-bed the first thing to be done is to provide a sufficient area of ground to allow of the area of the surface of the top sand being sufficient to allow the required quantity of water to descend at a rate of not more than 6 in. per hour. Thus, every 100 square feet of filtering surface will pass 50 cubic feet of water per hour, and the quantity required to be passed through being known, the requisite area is thereby ascertained.

The bottom and sides of the filter-bed are made water-tight, usually by puddling them with clay, well cut, cross cut, and trodden, with the help of water to facilitate the work; but it is necessary to guard against using too much water, otherwise the structures afterwards to be erected upon the puddling will be subject to displacement. The thickness of puddle is usually about 18 in., and this should be worked in three layers, the tools used for cutting the clay being not less than 10 in. long, and they should be driven completely through the second and third layers and well into the first and second respectively.

In point of economy of construction, and where sufficient land can be easily acquired, an excavation of the ground, having slopes of two horizontal to one vertical, the excavated material being embanked round it, is preferable; but there are situations in which, for want of room, vertical walls have to be resorted to, to economize space. In the former case the slope of the excavation is cut down in level benches or steps to prevent the clay puddle that is to be placed upon it slipping down, or "spewing out."

The bottom and sides of the filter-bed having been rendered water-tight, it is usual to cover over the puddle with concrete to the depth of about 6 in., to form a foundation for the brick or other paving with which the filter-bed is lined. Where the whole of the space of ground at command is required for the filtering area, vertical walls are employed to sustain the sides of the filter-bed. They are sometimes arched on plan, with counterforts, whereby the wall material is economized, or, else they are made straight, as ordinary retaining walls, with counterforts behind.

There is a third method employed, where the space, although limited, admits of some margin for slopes, and where gravel or other material for concrete is abundant. It consists of walls of concrete with a slope on the face of about 1 to 1, while the back, if the ground is of a stiff nature, as clay or marl, is stepped.

The concrete is usually faced with brick on edge to protect it from the action of frost, which would gradually wear away its surface. Ice formed merely on the surface would fall harmlessly away, but ice formed within the interstices of the

concrete would, by its expansion, disrupt it and gradually wear it away.

For continuous working it is necessary to make the filter-bed in two divisions. It is better, except for the matter of expense, to make it in three, or even four; but it must be made in at least two divisions, in order that one may be shut off for the purpose of having the deposited matter removed from the surface of the sand while the other is in action.

The bottom and sides of the filter-bed having been formed in one or other of these ways, a brick drain with open joints, or, if the filter-bed be small, a perforated pipe is laid along the centre, and from it branches of perforated pipes, or other kind of perforated drains, are laid with a rise towards the sides, and from the upper ends of these branch drains air pipes are carried up the slopes, or the walls, as the case may be, terminating above the water level. Their ends are often covered with ornamented cast-iron perforated caps. These pipes are for the purpose of allowing the air contained in the drains and the interstices of the gravel, and which is displaced when the filter-bed is charged with water, to escape through them. Some engineers dispense with air pipes, but it is at the risk of a displacement of materials in the bed.

The drains having been laid in, and the body of each pipe packed up on each side with gravel to prevent its lying hollow on the floor, and so being liable to fracture by the weight of materials above it, the spaces between the drains are filled in with gravel or broken stone of the size of hens' eggs, and more material of the same size filled in, so that over the highest parts of the drains there shall be a depth of not less than 6 ins. of this coarsest material, the surface being brought level throughout.

Upon this first layer of materials another of 6 in. in thickness is laid, of finer gravel, of the size, say, of small walnuts. On this, again, a layer of bleached and perfectly clean shells, 3 in. or 4 in. in thickness, is laid, cockle shells being the more generally employed. Some engineers deny that shells are necessary. Perhaps they are not. Their purpose is to completely separate the finer material lying above them from the coarser beneath them, and to prevent the one running in amongst the other; and any other method that prevents this mixture equally well answers the purpose; but without shells the several layers have to be graduated by smaller degrees, and so a greater number of layers of different degrees of fineness employed, while shells act at once as a complete prevention of the mixture of the sand with the gravel.

Upon the shells a layer of coarse sand 4 in. or 5 in. in thickness, is laid, and finally a depth of not less than 2 ft. of fine sand. It depends on circumstances whether a depth of 2 ft. is sufficient, or whether 3 ft. should be laid on. The oftener the filter-bed requires cleaning, according to the turbidity of the water to be filtered, the greater the thickness should be, for on each occasion of cleaning, a portion of sand is removed with the mud, and the depth of it gradually reduced. It should never be reduced to less than 1 ft. in depth.

This fine sand should not be too fine. Some engineers have aimed at procuring the finest sand that could be had; but there seems to be a little mistake in this, for sand a degree coarser will allow the descent of the water more freely, and at the same time arrest the mud equally well; for the action of the sand on the water, or rather on the particles of solid matter it contains, is not limited to an arrestment of the solid particles on the surface, but acts under the law of aggregation; the particles of sand, being larger than the particles of mud, attract them to themselves during the passage of the water through the first inch or so in depth of the same, and it is not until the interstices of these grains of sand become choked that the filtering action ceases, thus allowing the filtration to go on for a longer period than it does when the finest sand is used; and as (although the mud does not penetrate the finer sand so far as it does the sand not so fine) the mud cannot be removed from the surface without taking with it some small depth of sand also, it is more desirable to take the benefit of this action of aggregation of particles, and so obtain a longer period of action of the filter-bed.

All the materials must be washed perfectly clean before they are deposited, and this is best done by a hose and jet under a powerful head of water, or under its equivalent, great pressure. The sand is readily washed in this way by allowing it

to run gradually into a wide trough, set in an inclined position with its lower end open, through which the water runs away to a drain provided to carry it off, the jet of water being directed against the sand in the trough from the lower end, and its action continued until the water runs away clear.

The finished surface of the sand should have a slight inclination, and the supply pipes should enter at the lower end. The ends of the supply pipes should be enclosed by troughs, over the edges of which the water flows on to the sand, and as this point of entry is the lowest part of the surface of the sand, the water fills the space appropriated to it without disturbing the sand.

When the action of any division of the filter-bed has gone on long enough, the supply is stopped and the water allowed to sink away, all but the last few inches in depth, which would be so long in running off through the sand that a drain pipe is provided to carry it off from the lower end of the bed. This drain pipe has several inlets, surrounded by wicker baskets or similar protection, to prevent the sand entering the pipe. As to the depth of water to be allowed over the sand, the late Mr. Simpson allowed from 4 ft. to 5 ft.; Mr. Hawksley allowed 2 ft. at Leicester; while Mr. Bateman allows only 1 ft. But these differences are not very important. It is the difference between the level of the water in the filter-bed and that in the filtered water well which governs the rate of speed with which the water passes through the filter-bed, and not the mere depth on the bed. If one of these depths be preferable to another, the greater one is perhaps to be preferred, because it admits of a more powerful draught on the water, in any case of emergency for a short time, while, on the other hand, there is a saving of the materials of construction by making the space above the sand shallower.

These are the principles on which filter-beds for the water supply of towns are constructed, but for smaller quantities of water, various kinds of apparatus have been devised, through which water is forced, and in a measure clarified; but the very fact of forcing the water through being necessary, indicates a too small surface of filtering medium, and consequently an early stoppage of the pores of the material.

There was a filter in use in the woollen districts of Yorkshire, which was filled with shoddy, a kind of pulp of woollen rags, which clarified very dirty water well enough for a short time, but the constant stoppages for cleaning made it very inconvenient.

Then there are other substances which act chemically on water, but they are not employed on a large scale. The substances that have been used are animal charcoal, vegetable charcoal, silicated carbon (so called), and magnetic carbide.

Dr. Letheby says animal charcoal possesses the power of bringing the oxygen dissolved in the water into chemical union with organic matter, and so destroying it, especially when the organic matter is in a state of decay and in an unwholesome condition. A certain time is required to allow the water to remain in contact with the charcoal; it must be in contact for a minute at least. A cubic foot of animal charcoal weighs from 50 to 52 lbs., and holds within its pores four gallons of water; and, therefore, allowing one minute for contact, water could not be filtered through it at a greater rate than four gallons per minute per cubic foot. The thickness of the charcoal bed is of little moment; it is the quantity of charcoal to the quantity of water that is to be considered. It is found that water cannot be forced through a filter containing 80 lbs. of animal charcoal, so as to be effectually purified at a greater rate than 400 gallons a day, whereby the water is in contact with the charcoal, on the average, during a working day, for six or seven minutes. For house cisterns, animal charcoal is very valuable, and is a safeguard against the presence of organic impurities in water.

Dr. Frankland agrees with Dr. Letheby as to animal charcoal, but says that vegetable charcoal is inert in its action on organic matter.

Mr. Thomas Spencer introduced the magnetic carbide, and has applied it on a tolerably large scale at Wakefield, where the water is very impure before filtration, containing large quantities of sewage; and so far as is at present known, this substance and animal charcoal are the only two of the four named that have had any success, even on a small scale; but

they are expensive processes, and it seems that it would be more economical to go to the expense of keeping sewage and other contaminations out of the water altogether than to employ these methods of purification.

It is obvious that where water for the supply of a town is taken from a public river, it is necessary to filter it before delivery to the houses; but it is not so obvious that filtration is necessary or desirable where the source of supply is an uninhabited hilly district. The water supplied to Manchester is not filtered, except through copper-wire gauze strainers, neither is that supplied to Glasgow; yet it is bright and sparkling when not tinged with the color derived from the peat that lies in patches within the drainage area. And to remove the color derived from peat is very difficult, if not impossible, by filtration on a large scale. Filtration of water, while removing impurities, renders it in a measure vapid, and although the presence of salts of lime in certain hard waters preserves its agreeable taste even after filtration, it was probably a wise foresight that led the engineer of the works above named to dispense with filtration, the water at both places being of a very soft character.

The well-known household filters all depend for their efficiency on animal charcoal—that is to say, it is generally understood that they do, but some of the "patentees" make a good deal of mystery about what their efficiency depends on. The different forms of these filters, however, probably constitute their only difference. The form adopted by the Water Purifying Company of the Strand, London, is a good one, consisting of a charcoal filter placed inside the house cistern. The water passes upwards through the filter and through a pipe led from the top of it over the side of the cistern and down the outside to a level below the water level of the cistern, so that the pipe becomes a siphon. A recent improvement in Mr. Lipscombe's filters consists in adding to the cistern a dirty-water pipe, through which water is drawn for purposes not requiring clean water, by which means the accumulation of dirt under the filter is prevented, the pipe being so connected that the cistern water is drawn through the space beneath the filter when the tap is opened.

AMERICAN ENGINEERS IN INDIA.

From "Engineering."

Had Lord Mayo's recently expressed intention to commence the extended railway system of India upon a new model, and that model American, and of soliciting American engineers to come and teach the Public Works Department how to build cheap railways, been announced a few years ago, opinions so heterodox as must have led to those conclusions would have been denounced with indignation, not only by English engineers, but in England universally. Only a short time since, it was popularly understood that whatever was good in American railway practice was not new, and that whatever was new was not good; that American lines were loosely thrown together, haphazard, without surveys, without grading, without ballast or drainage, over prairies where the grass was scarcely disturbed in laying the track, through forests cleared to a width barely sufficient for the passage of trains, round mountains, in curves laid out by eye, across streams on perilous wooden structures doomed to conflagration. And over these rough roads it was deemed impossible to ride even for a limited period with safety. If collision were happily avoided, it was only that the train might leave the rails and dash itself into a wreck, or crush through one of the fragile viaducts, or fall down a bank, to resolve itself into a burning mass of carriages at the bottom. But though popular ideas move slowly, they gradually grasp unmistakable facts surely, and as the mists of uncertainty and ignorance pass away, such facts remain behind, and retain their unmistakable outline. So by degrees the true knowledge of American railway practice has been forced into the public mind, until at last it is being understood that in constructing railways suited to their peculiar requirements, the United States engineers have done at home what we have hitherto failed to accomplish

abroad, and it is even considered wise to turn to them for assistance in the formation of our Indian lines. The absence of much real and definite information upon American railway construction, and the existence of so many vague and monstrous statements as to its principles, and the recklessness which attended the formation of works, fostered the prejudice which almost as a thing of course existed against a Transatlantic system. But great undertakings, triumphantly accomplished, stand out in bold relief, and the completion of the Pacific Railway disposed at once and for ever of most of the doubts and prejudices existing. The Americans had made the longest line in the world with unequalled rapidity, and so brought the western seaboard of the continent within 17 days' journey of Liverpool. For the rest, the constantly repeated examples of American railway enterprise and skill, and the descriptions and illustrations of the leading United States railway works in our columns, have succeded in conveying to the general public a clear conception of the every-day practice in the States.

The successes which have attended the efforts of American engineers in establishing a vast network of lines connecting far distant towns, and opening up remote eligible lands which lay beyond, hopelessly unprofitable tracts, form a strong contrast to all that we have attempted in our colonies, and especially in India, where an extensive mileage has been constructed, although only a very small proportion of all that is urgently required. And these latter, built at a cost more than double of their original estimates, present work which, for flimsiness of construction and carelessness, can hardly be surpassed even in America. The excessive cost of their formation has thrown a burden upon the country, and hindered the cause of railway extension in India; in other words, it has checked the employment of armies of native workmen; it has prevented the development of the country; and it has deprived India of the means of access and free internal communication necessary to all countries, but of vital importance to a military settlement. A costly experience has therefore shown that the system hitherto adopted has been a failure, that the enterprise of private companies, however serviceable for pushing forward works, has proved entirely unsuccessful under the guarantee system. On the other hand, the competency of the Public Works Department has not been brightly illustrated by the conduct of undertakings under its charge, without taking into consideration the bitterness and jealousy which have split this section of the Government staff into schisms and internal antagonism, and which would promise but little for the economical and rapid progress of work if it were carried out by the joint efforts of military and civil engineers.

In this difficulty the plan has suggested itself to introduce a new system, to be carried out by new engineers, whose training and experience have taught them to observe rigid economy on the one hand, and to push work to completion with the utmost rapidity on the other. Hence we are told the American system is to be tried, and by American engineers.

In taking this step we believe the Indian Government to be hardly nearer to the real solution of the problem than in the old days of private companies and guarantees. Long ago we pointed out, and have often repeated our assertions and arguments in favor of the American system of railway construction being adopted in India and our other colonies. It is exactly suitable for the purpose. Having to run for hundreds of miles, it may be through unprofitable country to ultimate objective points, it follows that such lines should be constructed as cheaply as is consistent with safety and moderate speeds. These are not permanent roads; they are but the precursors of the more durable lines—the pioneer ways by which all parts of the country may be united, and which, as the growth of trade and the value of the lands increase, will be slowly reconstructed solidly and at a greater cost, so that ultimately the trunk lines of the future railways of India will be what engineers intended the railways to be in the outset. This is the whole secret of the so-called "American railway system," to construct only such works as are absolutely necessary, and to construct them under proper organization.

But the services of American engineers are no more indispensable for carrying out this system than are the labors of United States citizens for the manufacture of American cloth; and, while it is probable that a full staff of Transatlantic engineers

transported to India would find themselves infected with the evils of the existing regime, it is certain that if a few only were employed any benefit expected would be simply lost in the preponderance of opposing views and conflicting practice.

It is absurd to imagine that the American engineer possesses in himself any special capacity differing so widely from that of his English professional worker, so as to make the former naturally suited for carrying out work better than the latter can hope to do. Training, experience, and specialty of employment do much; but we venture to say that there is no average English engineer who cannot do as well or better than the average American engineer, provided he were relieved from the tedious trammels of routine, and left to carry out work with a similar freedom of action. That the principle and not the individual is at fault is shown by the readiness with which Englishmen occupying professional positions in America and Canada fall into the admirable and national system which rules there.

Many of the formidable items which have burdened English railways, and weighed so heavily upon our colonial lines, are unknown in the States. Costly law charges, consulting engineers' heavy fees, and palatial offices are unknown. The engineer's staff is not so large, his remuneration far smaller, and yet his duties are more onerous; he takes the field more actively, he saves his principals many heavy charges for contractors', engineers', and agents' services; in short, the superfluous costs which have made many of our undertakings insolvent at home and abroad are unknown in the States, as they ought to be at all events upon our colonial work. An American engineer would be incredulous if he heard that the maintenance of the Public Works Department amounted to so large a percentage of the amount expended.

The solution of the Indian railway difficulty does not seem to lie in the transfer of its works to American engineers. So doing would only have the effect of complicating the existing difficulties, which unfortunately are now serious enough, while there would be no security for more economical construction. But what is wanted is the adoption of the American system in its constructive principles and its organization; that system is well understood, and may soon become familiar to all engineers employed by the Government, and being understood it may, by official help, be efficiently carried out. But it must be remembered that it would clash with the present military regime, that much routine and formality would have to be swept away, and give place to a freedom of individuals and a personal responsibility which would be probably distasteful to the Public Works Department.

And before any earnest service can be be effected, the difficulties between the civil and military branches of the service must be removed, the whole of the principles and practice which have guided the Department should be thoroughly investigated, and the causes which have led to the perpetration of so much bad work, and so much costly work, must be ascertained. This done, the inherent evils of the Department would be made known, and the path to real reform would be then open. But until defects are thoroughly brought to light, remedies cannot be instituted, and in the meantime the partial employment of American engineers upon Indian railways would prove rather an evil than a benefit.

To Render Timber Incombustible.—This has hitherto been done by saturating the wood with some soluble silicate. A new method is described in the "Neues Jahrbuch fur Pharmacie." Herr Reinsch states that, having been reqested to report to a fire insurance company about the best means of preventing timber bursting into flame, he experimented with various salts, and at last came to the conclusion, as the result of his experiments, that impregnating timber with a concentrated solution of rock-salt is as good, if not better, a preservative against its bursting into flame as water-glass (silicate of soda), while the price of the former salt is, of course, only a mere trifle ; moreover, rock-salt thus applied to timber is a preservative against dry rot and noxious insects. The author recommends the use of salt water, that is to say, a solution of rock-salt of moderate strength, for the use of fire-engines during a fire, as by far more effective than water; but in order that the salt should not injure the working parts of the engines, they will immediately afterwards have to be played with fresh water again.

IRON ARCHES.

From "The Mechanics' Magazine."

The adoption of cast and wrought iron archers and girders for the purposes of railway traffic was a sad blow to the hopes and expectations of the advocates of the old stone type of construction. Nevertheless, with a laudable desire to make the best of their dissappointment, they comforted themselves with the idea that stone bridges would still be employed for ordinary roads, and in other situations where the limitations imposed upon the span, headway, rise, and load, were not of the same stringent chzracter. Latterly, however, these pleasing illusions have been dispelled. Bridges have been built over roads, rivers, and in other localities where their duty was not to carry locomotive traffic, and iron, either cast or wrought, has been the material selected. The recent completion of new Blackfriars Bridge affords another instance of the substitution of iron for stone, and in all probability another arch of the latter material will never throw its shadow on the waters of Old Father Thames. Omitting other considerations which are foreign to the comparison, what is the chief, the fatal objection, to an arch of stone? In a word, it is the rise. It is absolutely necessary to adhere to a minimum proportion of rise to span, and this adherence becomes impossible under certain conditions of headway and traffic. Engineers are therefore compelled to seek, either in another material or another principle of construction, for those qualities which they fail to find in that formerly in use. It is true that in arches of iron, either cast or wrought, there is also a limit to the proportion of rise to span, but the ratio is a great deal smaller than in those of stone. Moreover, by special treatment the rise may be confined to points not very remote from the springings, and the crown of the arch be practically perfectly flat. No such a disposition is practicable with stone or brick arches. This adoption of a flat crown was very successfully carried out by Mr. Page in the construction of the present Westminster Bridge. It was effected by introducing a horizontal wrought-iron plate girder for a certain length along the crown of the arch, and bolting it to the haunching or springing segments, which are of cast-iron. The span of the largest arch is 120 ft., and the length of the wrought-iron girder introduced at the crown 70 ft., so that the actual rise of the arch does not increase beyond a distance of 30 ft., from each springing.

So far as mere span is concerned, where there is nothing to prevent the proper rise being obtained, a stone arch can bear a very favorable comparison with one of iron. The Grosvenor Bridge over the river Dee, near Chester, has a clear span of 200 ft., and is the finest stone arch in existence. On the other hand, the central arch of Southwark Bridge is 240 ft. in span, and, in spite of its unscientific design and distribution of material, is yet a fine specimen of cast-iron construction. Its great span and rise give it a bold outline, which unfortunately is very much marred by the bad appearance of the piers, which are little better than those supporting its neighbor of Vauxhall, higher up the stream. The expectation that, with the substitution of iron for stone in the construction of arches, much larger spans would be reached, has not, with one or two exceptions, been fulfilled. With the exception of Southwark Bridge and another, to which we shall presently allude, all the arches of the iron bridges over the Thames are inferior in span to that of the stone structure over the Dee. The truth is, that the mania, if the term may be used professionally, for large spans has died out. Unless there are no other means available,engineers do not advocate the employment of very large spans in iron-work. The reason is, that the weight, and consequently the cost, of the superstructure increases in a very disproportionate ratio to the span. There is manifestly, therefore, a certain proportion of span and a certain number of piers—or, what is the same thing, a certain number of spans—which will fulfil the conditions of maximum economy. Colonel Kennedy was the first to reduce this principle to practice, and adopted, with one or two unavoidable exceptions, a uniform span of 60 ft. for the spans of the bridges along the whole of the Bombay and Baroda line in India. There is very little doubt but

that the span of 60 ft. is too small, and greater economy would have resulted from adding ten or even twenty additional feet to it.

In one of the first attempts to substitute cast-iron for the older material—stone—in the construction of arches, the transition or the difference was very small, and consisted solely in the adoption of a different material. The same form and the same principle of voussoirs or arch stones were retained in the building of the Sunderland Bridge, with the exception that they were formed of hollow cast-iron, and bolted together through flanges cast for the purpose. This was clearly a servile imitation of what had been already accomplished with stone, and iron cannot be correctly said to have been substituted for stone until the "rib" principle came into use. Numerous arches were constructed with cast-iron ribs, in which there was not the slightest attempt at accurate designing or scientific and economical distribution of material. So long as they were made strong enough, they answered their purpose thoroughly, and do so still at the present day. The difficulty of obtaining sound and reliable castings of large size induced engineers to construct arched ribs of wrought-iron. The two best examples of this nature are the Victoria Bridge, carrying the railway over the Thames at Chelsea, and the magnificent structure recently inaugurated by Her Majesty at Blackfriars. Theoretically, cast-iron, from its great resistance to a compressive strain, is the most suitable and economical material to employ for the construction of arches, and it might be used in that situation a great deal oftener than it is. Engineers have conceived a bad opinion of cast-iron from the failures with which it has been attended in some isolated instances. At the same time they altogether overlook the important fact that these failures were due, not to the unsoundness or weakness of the material itself, but were entirely owing to the circumstance of it being placed in a situation and subjected to strains for the resistance of which it was not adapted. It is very probable that, by a pardonable *esprit de corps*, engineers prefer to lay the blame of these failures upon the material rather than upon the designers. But, as we have now arrived at a more scientific period, and are, from past experience, fully enabled to form a correct estimate of what may be fairly and reasonably expected of cast-iron, there is no necessity for refusing to accord to that metal the merit which unquestionably belongs to it.

There are abundance of cast-iron arches carrying the various railways over the suburban roads of our metropolis, which have done duty for 20 or 30 years, and are "as good as new." There can be no question of their strength and stability, and it is difficult to comprehend why some engineers are positively afraid to erect similar structures, but, in their place, substitute others of a more expensive character. Where the span is large and the bridge intended for railway purposes, it is a question for consideration whether wrought-iron should not be used instead of cast, especially if the rolling load bears a very large proportion to the fixed weight of the bridge. But in a bridge intended for ordinary road traffic, where the conditions of the ratio of the fixed to the rolling load are inversed, there is no valid argument against the employment of cast-iron within proper limits. The rejection of cast-iron in situations where it is peculiarly applicable, is a piece of professional pusillanimity which has had its origin in the ignorance and incompetency of some of the members.

A French writer calculated that, at the commencement of 1867, there existed in the world 2,814 light-houses, or phares, of more or less importance, viz., 1,785 on the coasts of Europe, 674 on those of America, 162 in Asia, 100 in Oceania, and 93 in Africa. As regards Europe, the best-lighted coasts are those of Belgium, France following immediately afterwards. Then come, in the order in which their names are given, Holland, England, Spain, Prussia, Italy, Sweden and Norway, Portugal, Denmark, Austria, Turkey, Greece, and finally Russia. Besides Europe, the best-lighted coasts are those of the United States, which have one light for every 20 miles, whilst the Brazilian coast has only one light for every 87 miles. Of the 2,814 in existence at the commencement of 1867, about 2,300 have been established since 1830, while the power of the greater part of those existing prior to 1830 has been increased.

ON CERTAIN ECONOMICAL IMPROVEMENTS IN OBTAINING MOTIVE POWER.

By MR. RICHARD EATON.

Condensed from "The Engineer."

The British Association for the Advancement of Science having, in their programme for the present session, invited contributions on the momentous subject of the economy of fuel, it is conceived that some description of a discovery in that direction, called the Warsop aero-steam engine, may not be without interest.

It is now pretty generally allowed that power and heat are convertible terms, and we have it upon the highest scientific authority, that a unit of heat is equivalent to 772 foot-pounds. We are further informed that one grain of coal produces by combustion sufficient heat to raise the temperature of 1 lb. weight of water through 1.634° Fahr. Taking the mechanical equivalent of heat at 772 lbs. per unit, as above stated, it follows, therefore, that the combustion of one grain of coal = 1261.45 foot-pounds.

Now, with the best pumping engines, either on the "Cornish" or "Woolf" system, the average duty is equivalent to about 94,000,000 foot-pounds, with a consumption of 94 lbs. (1 bushel) of Welsh coal—in other words, 143 lbs. per 1 grain of coal, as compared with 1261.45 lbs.; whence it appears that the steam-engine, in its most improved state, is not able to develop into useful power much more than one-tenth of the mechanical power due to the combustion of coal.

As a rule, we may assume that the more distant the extremes of temperature in a thermodynamic engine, the larger will be the proportion of heat turned into power.

In the steam-engine, the extremes of temperature, or the difference in the temperature of the boiler and condenser, are not very great, and air-engines, therefore, in which greater extremes may be employed, offer certain advantages in the production of power. But in their arrangement, construction, and practical working, many difficulties occur.

The difficulties in question arise, first, from the destructive action of the heating furnace upon the generator, which, when unprotected by water, is sooner or later burnt out or destroyed. Secondly, when high temperatures of air are employed, the wear and tear of working parts becomes very great, and the difficulty of proper lubrication almost insuperable. On the other hand, if low temperatures be employed, the engine develops but little power in proportion to its size, and the consumption of fuel becomes quite as large as, if it does not exceed, that of ordinary steam-engines.

In the consideration of the subject before us, a useful lesson may be learned from the avocations of domestic life. Let the tea-kettle be our monitor. The careful housewife places it, duly cleaned and charged, upon the fire; and no matter how sharp and clear may be the draught, nor how vivid and intense the gaseous flame, no harm ensues. Let her, however, neglect to keep it replenished, and what occurs—the bottom is destroyed. The water acts as a shield or safeguard to the metal exposed to the vivid incandescence, and in the present state of our knowledge as to the structure of metals, or their behaviour when exposed to sharp heat, it is difficult to devise a better protection.

The difficulty above mentioned has hitherto proved insuperable, notwithstanding the best efforts of those apostles and pioneers of the air engine, Stirling, Ericsson, and others. All the ingenuity expended upon the designing and construction of regenerators for utilizing to the utmost the heat of the escaping air, proved, unfortunately, of no avail so long as the generator, which was the mainspring of the whole, to say nothing of the working cylinder itself, remained liable to premature destruction.

Mr. George Warsop, of Nottingham, as the son of an air-gun maker there, was born with aerial ideas, which, although his only education was received at a Sunday school, and he was sent to work at ten years of age, he turned to such good account that, before he was twenty, he had, in leisure moments, secretly constructed an air-engine. Later in life it was his privilege, whilst a working mechanic in New York, during his engagement with Mr. Ericsson, to observe the weak points in the system of that highly gifted and

persevering inventor, and after years of research, to supply the deficiencies by a marvellously simple system of mechanism, which, so far as present experience goes, promises complete success, by means which, happily for the cause of economy and progress, are compatible alike with physical science and mechanical construction.

It is proposed, first, to describe these means; secondly, to enumerate the carefully ascertained comparative results which have followed their application; lastly, to show that these results are in accordance with sound theory.

In the first attempts at practically carrying out the system, the arrangement adopted consisted of an ordinary high-pressure engine, with vertical boiler, as used in the midland counties, where fuel is cheap. An air-pump is added, which is put in operation by the action of the steam-engine. Thus, cold air is taken in by the air-pump, and is forced on in its compressed state, through an air-pipe, which is conducted first within the exhaust, then in a coiled form down the funnel of the boiler, then past the fire, and finally past a self-acting clack-valve, at the bottom of the boiler, into the boiling water itself. Rising naturally through the water, the air is intercepted and subdivided by diaphragms of metal gauze. Thus a two-fold service is rendered by the contact of the elements, the water becoming aërified and deprived of its cohesion, and prompted to a freer ebullition; whilst the air, on rising above the water, is saturated by the steam, and the two together pass on to their duty in the cylinder, where saturation assists lubrication. The agitation of the water prevents scaling.

The machine thus constructed, but having two air-pumps, with cam motions applied to the valves, as also to the puppet-valves of the working cylinder, gave the following results—results which, it must be admitted, were sufficiently discouraging to have deterred the inventor and his associates from proceeding further in the matter, but for their faith in the intrinsic soundness of the system, and perseverance in carrying it to a practical issue. The work had to be done under disadvantages of various kinds, on inconvenient premises, which, centuries back, were a farm house standing within the ancient walls of Nottingham; and, until the protection of the patent laws had been obtained, the original apparatus was carefully guarded in an unsuspected attic. The results I proceed to detail:

Combined Air and Steam Engine.

Coals consumed during experiment	110 lbs.
Weight on brake	75 lbs.
Duration of experiment	140 min.
Number of revolutions of brake	4,623
" " " per min.	33
Gross horse-power of useful work done	182
Gallons of water evaporated during experiment	84

Steam Engine only.

Coals consumed during experiment	110 lbs.
Weight of brake	75 lbs.
Duration of experiment	115 min.
Number of revolutions of brake	5,182
" " " per min.	45
Gross horse-power of useful work done	204.1
Gallons of water evaporated during experiment	66

It is needful to state that the amount of air passed into the boiler in a state of compression, was considerable, being as much as 43 per cent. of the effective cubic contents of the working cylinder, or consumption of combined fluid from the boiler. And it appeared pretty certain that the power obtained by the increase of volume of the air admitted (due to the treating of it) did not compensate for the power consumed in working the two air-pumps which forced it into the boiler. At the same time the difference in the useful effect in the two modes of working did not appear to be so great as the power required in handling the pumps led one to suppose it would be. Hence there appeared an evidence of a certain latent gain which needed only development. To effect this, one of the air-pumps was discarded, and experiments made by means of waste holes, drilled through the walls of the remaining one, to ascertain what proportion of air admitted to the boiler fully compensated for the cost of compression. And it was found that about 10 per cent. of the effective consumption of fluid in the working cylinder gave much more favorable results. At the same time the cam motions were discarded, and the air-pump valves left to their own unaided action. The results are given in the subjoined table:

Combined Air and Steam Engine.

Coals consumed during experiment	140 lbs.
Weight on brake	124 lbs.
Duration of experiment	195 min.

Number of revolutions of brake	8,463
" " " per min.	43.4
Gross horse-power of useful work done	551.1
Gallons of water evaporated during experiment	104.3

Percentage of gain in work done by combined engine as compared with that done by steam only, 42½ per cent.

Steam Engine only.

Coals consumed during experiment	140 lbs.
Weight on brake	124 lbs.
Duration of experiment	145 min.
Number of revolutions of brake	5,942
" " " per min.	41
Gross horse-power of useful work done	386.9
Gallons of water evaporated during experiment	64

Here, although a very remarkable relative economy was apparent, it became obvious, on consideration, that danger of mistake would arise in assuming this economy as absolute, inasmuch as the duty performed, when contrasted with that obtained from engines of standard types actuated by steam, was manifestly low, and it seemed probable that, as by judicious improvement in details, the duty was made to approximate more closely to fair steam-engine duty, this relative economy might fall off considerably, inasmuch as there would be less margin to economize upon.

With the view of testing this point, and also, for the satisfaction of railway engineers, of conducting experiments at locomotive pressures, a thorough remodelling of the whole apparatus was effected. The tappet motions were thrown aside in favor of the usual slide-valve arrangement, working with a moderate amount of expansive action. The former wasteful vertical boiler was discarded in favor of a more economical one of the compound or Cornish multitubular description, so as to obtain a better evaporative duty from the coal consumed. The radiating surfaces of the cylinder pipes were re-clothed, and the feed water heated by the exhaust steam. Instead of exposing the air-pipe to the *direct* heat of the furnace, as in the former case, the air became thoroughly heated in its passage from the pump to the boiler, to a temperature of from 500 deg. to 600 deg. Fahr., by being conducted through suitable coils and pipes through the exhaust steam in the heater, and the waste heat in the boiler flues and uptake.

The general arrangement adopted will be readily understood. The air is forced by the air pump through a tube of ordinary wrought-iron, and of 1¼ in. internal diameter into coils in the regenerator, which is heated by the exhaust steam; thence in a straight line to the uptake, down which it passes through a coil into the flues beneath the boiler, and through another coil in the smoke-box; thence back to the front of the boiler and past the clack-valve, and is led down by an internal bed to the bottom of the boiler water space, where it is evenly distributed along the whole length by a perforated pipe, and the results are given in the following table:

Combined Air and Steam Engine—Open Valve Trial —Damper wide open throughout.

Coals consumed during experiment	140 lbs.
Weight on brake	120 lbs.
Duration of experiment	234 min.
Number of rev. lutions of brake	22.815
" " " per min.	97.5
Gross horse-power of useful work done	1428.05
Gallons of water evaporated during experiment	131.25
Weight of fire left in furnace when engine stopped	43 lbs.

Percentage of gain in work done by combined engine as compared with that done by steam only, 27.994 per cent.

Steam Engine only.

Coals consumed during experiment	140 lbs.
Weight on brake	120 lbs.
Duration of experiment	196 min.
Number of revolutions of brake	17,825
" " " per min.	90.94
Gross horse-power of useful work done	1115.7
Gallons of water evaporated during experiment	112.5
Weight of fire left in furnace when engine stopped	28¼ lbs.

Combined Air and Steam Engine—Even Pressure Trial—Damper Varied.

Coals consumed during experiment	112 lbs.
Weight of brake	120 lbs.
Duration of experiment	153 min.
Number of revolutions of brake	15,433
" " " per min.	101 nearly
Gross horse-power of useful work done	972.55
Gallons of water evaporated during experiment	93¾
Weight of fire left in furnace when engine was stopped	53½ lbs.

This trial was conducted on the same principle as that followed by The Royal Agricultural Society, the engine being stopped in each case when it ceased to perform ninety revolutions per minute. Percentage of gain in work done by combined engine as compared with that done by steam only, 47 per cent.

Steam Engine only.

Coals consumed during experiment	112 lbs.
Weight on brake	120 lbs.
Duration of experiment	112 min.
Number of revolutions of brake	10,500
" " " per min.	93¾
Gross horse-power of useful work done	661.69
Gallons of water evaporated during experiment	68¾
Weight of fire left in furnace when engine was stopped	34 lbs.

15,433 revolutions under steam would have required 100 gallons of water.

It is right to mention that in all the before-detailed experiments the Prony brake, with the best modern improvements, was used as the measure of useful work done, and every care taken in the conduct of these trials to determine accurately the amount of water evaporated and the duty done in useful effect by a given amount of fuel. Other observations as to temperature, indicator diagrams for determining the cost of the air compression in proportion to the power developed, and various useful notes were obtained, which it would be out of place to recapitulate here at length; but all these details are at the disposal of the Association, or any scientific persons interested in the subject. Professor Tyndall has volunteered to investigate the scientific bearings of the results which have been personally observed in Nottingham by that accomplished amateur engineer, Lord Richard Grosvenor, and by other engineers, several of whom have already applied to be licensed to make.

It remains to submit to your consideration the theory of our system.

We have here a machine which, when worked as an ordinary steam-engine and boiler, performs as respectably in its brake duty as an average well-constructed commercial engine not designed to work with a high rate of expansion, and we find that the addition of the pneumatic arrangements considerably enhances the amount of its useful duty.

Let us now endeavor to ascertain in what manner the gain in question arises, premising that the following condition of things can exist only in theory.

Suppose a boiler to be theoretically perfect, wasting no heat, and its feed level maintained only just constant, the quantity of water evaporated being infinitely small, and friction of all kinds to be eliminated in the machinery. Then the power required in compressing any given amount of air at atmospheric density will be recouped by the power generated by the re-expansion of the air so condensed, action and reaction being equal.

Let us now ascertain the cost of obtaining a given quantity of steam at a given pressure, as compared with the like quantity of air at the like pressure; and, for sake of example, we will take 150 cubic ft. in each case at 60 lbs. pressure per square inch in gauge.

Here the relative volume of the steam to the water which is generated would be, in the case of 60 lbs. pressure (307° Fahr. about)=355 to 1, according to "Regnault."

And it follows that the 150 cubic ft. of steam under consideration was generated from a three hundred and fifty-fifth of its volume of water originally, or .422 cubic ft.

The weight of 1 cubic ft. of water being 62.32 lbs., the weight of .422 cubic ft. would be 26.3 lbs. Now, to raise 1 lb. water from 52 deg. Fahr. to 212 deg., or through 150 deg., requires 150 heat units; to convert it from water at 212 deg. into steam at any pressure, 966 units, making a gross total of 1116; and as the conversion thus of 1 lb. of water requires 1116 heat units, it would follow that the conversion of 26.3 lbs. of ditto would require 29,350 heat units, which is the cost of obtaining 150 cubic ft. of steam at 60 lbs. pressure.

In the case of the air, 500 cubic ft. at atmospheric density, and temperature 62 deg., would, by Marriott and Dulong's law, be transformed into 100 cubic ft., at 60 lbs. per sq. in. on gauge, supposing the temperature remained unchanged.

But this 500 cubic ft. of atmospheric air is, by the combined agency of the increase of temperature, due to compression, and the application of artificial heat in some form, brought from its original temperature of 62 deg. up to that of the boiler, viz. (that due to 60 lbs. pressure), 307 deg.; in other words, through 245 deg. Fahr.

Now the weight of 500 cubic ft. of atmospheric air = 38.05 lbs.—that of 1 cubic foot at atmospheric density, and 62 deg. temperature, being = .0761 lbs., according to Regnault's experiments. And we have seen that this 500 ft., at atmospheric density, and 62 deg. temperature, is equiv-

alent in value to 100 cubic ft. at 60 lbs. pressure and the like temperature; the weight therefore would be alike = 38.05 lbs.

The increase of volume from 100 cubic ft., due to the increase of temperature from 62 deg. to 307 deg., or through 245 deg., would be, according to the general formula applicable to the expansion of gases, about 50 per cent., or say roughly, as the volume would increase four hundred and eightieth of its bulk for each degree Fahr. increase of temperature, for 245 deg. increase the original bulk of 100 cubic ft. would be increased $\frac{1}{480}$ths, which is about 50 per cent.; the original 100 cubic ft., at 60 lbs. pressure per sq. in., now becoming 150 at the like pressure, and this weighs 38.05 lbs.

The number of units of heat which will be consumed in raising the temperature of this 38.05 lbs. of air from 62 deg. to 307 deg., or through 245 deg., the pressure remaining constant and the volume variable, as above described, will be, according to Regnault, the same as would raise the same weight of water through .278 deg.; 38.05 lbs. equivalent weight of water $\times$ 238 deg. Fahr. $\times$ 245 range through which raised = 2218.69 heat units, which is the cost of obtaining 150 cubic ft. of air, at 60 lbs. pressure, as compared with 29,350 heat units before mentioned in the case of the like quantity of steam—a very striking and remarkable difference.

Both these 150 cubic ft. are capable, when worked in a cylinder, of generating the same motive force, and are alike capable of being worked expansively; but it is an important consideration whether the loss in working the air expansively would not be greater, owing to its more rapid radiation and loss of heat, and consequent loss of volume and pressure.

Such a theoretical gain, viz., about 13 to 1, is evidently vastly far from being realized in the experimental engine, seeing that only about 13 per cent. of the whole cylinder consumption in the last experiment is passed into the boiler (in place of 100 per cent., as in the investigation above given), the remainder being supplied by the steam generated; thus, 13 per cent. *air* + 87 per cent. *steam*, and we must look to other causes, in addition to the above, to account for the economy realized in practice.

It is conceived that it is to the injection of air into the boiler that this may mainly be referred, for the following reasons: When steam is ordinarily raised from water, the heat expended is consumed partly in overcoming the cohesion of its particles, and in creating steam room for the vapor raised; and, further, in promoting the circulation of the water itself in the boiler. In all of these operations work is done, and the injection of the air accomplishes, practically, the work which, under the above mentioned circumstances, would have to be done by the heat; a much more intense and rapid circulation of the water is achieved, and the rapid ebullition and giving off of steam bubbles is greatly promoted.

Further, the air enters at a higher temperature, and its *direct* action upon the water is equivalent to an increase of evaporative surface—all the more efficient from being *direct*, instead of communicated by the conductive power of metal plates.

An experiment which has been repeatedly made goes far to confirm this view. Let the engine be running under steam, the pressure gauge rapidly falling, with the fire fast dying out. The putting the air-pump in gear will cause the gauge to mount several pounds in the course of a few minutes, and there continue for a considerable time, the engine meanwhile continuing to work as before, after checking a moment or two on first feeling the increased resistance due to putting the air-pump in action. And this result evidently shows that the evaporative duty of the boiler is increased immediately on the admission of the air, and irrespective of the state of the fire—a condition of things which is consistent with the foregoing explanation, and, indeed, scarcely perceptible of any other.

Opportunely does this discovery come in 1869, the centenary of the steam-engine.

A writer in a recent number of that valuable paper, the "Economist," remarks that "a single improvement to save 10 per cent. in fuel for the steam-engine would probably add more absolutely to the real wealth of this generation than the invention of the steam-engine itself added to the real wealth of the generation in which it was invented." After years of anxious reasearch, we now possess such an improvement, but of greater value. We are thankful for the opportunity of doing good in our day and generation.

A NEW METHOD OF UTILIZING SOLAR HEAT.

Translated from "Los Mondes."

This method is due to Mr. Delaurier, of Paris: A truncated cone, open at both ends, is silver-plated on the inner surface, and highly polished. The solar rays enter the large end, and, because of the equality ef the angles of incidence and reflection, converge at the small end. As the length of the cone is increased, the area of the smaller opening may be diminished, and the concentration of heat becomes greater. This simple contrivance, in the opinion of the inventor, may work out an industrial revolution, especially in Africa.

We quote from the inventor's description: "Heretofore we have made use of concave mirrors and lenses to concentrate solar rays. Everybody knows the difficulties attendant upon the use of large metallic mirrors having but one focus, and the great loss of heat caused by reflection.

"Lenses are not only a very bad means for concentrating radiant heat, being but little diathermic when thick, and, moreover, impossible of construction when one attempts to make them in sections.

"The process described has a further advantage in the fact that rays incident upon the surface at a small angle lose little by reflection; so that in this case almost all substances can be made good reflectors. But the chief advantage is cheapness and facility of construction. A common wooden box of the right shape, lined with tin, will be sufficient. If it is wished to get a greater concentration of rays let this pyramid be made long.

"Is it not possible by this means to obtain heat enough for ordinary purposes, especially for irrigation, by furnishing steam to engines suitably modified?"

M. Delaurier has also devised a means to prevent explosion of fire-damp, by a continual firing of the gas as soon as it is generated in small quantities in different parts of the mine. A wire runs through the mine from a Ruhmkorff coil which is kept constantly charged. This wire is cut at intervals deemed sufficient, and the ends are separated about 1 millimetre. With a coil giving a spark of 6 centimetres he cuts the wire in say 10 places in the highest parts of the mine, where the gas first collects. There is no need of a return-wire, the earth serving as well.

By this means the explosive compound of air and gas is set on fire as fast as the gas is generated, and the consequence is nothing more dangerous than a series of slight explosions. This is not very expensive; and the expense can be reduced by applying the process for a few minutes each day before the miners begin their work.

LIQUID FUEL FOR HEATING LOCOMOTIVE BOILERS—NEW EXPERIMENTS.

By H. SAINTE-CLAIRE DEVILLE.

From "Comptes Rendus" through "Polyt. Journal."

Mr. Paul Audouin has constructed a fire-hearth by which the problem of the use of petroleum, or other kinds of mineral or coal oil for heating furnaces or boilers, has been solved to perfect satisfaction. This fire-hearth is a simple chamber of masonry with a brick bottom on which the oil is dropped slowly through pipes, provided with cocks to regulate the supply of oil. The air required for burning the oil, is admitted through the holes of a perforated plate of fire-brick, standing upright, and forming the back-wall of the chamber. I have replaced this plate by a strong cast-iron grate of ordinary construction, which makes this apparatus more solid and more convenient without altering its principle.

Mr. Dupuy de Lôme and myself have used this improved apparatus with success for heating a tubular boiler on the French Imperial yacht Puebla. This boiler when heated with petroleum produced an effect of 60-horse power. We have proved by our experiments that petroleum is the

most manageable, and for Paris and many other places even the cheapest kind of fuel.

Shortly after the completion of these experiments, which were made in March and April 1868, Mr. Sauvage, Director of the French Eastern Railway, had the locomotive No. 291 put at my disposition for further trials with liquid fuel. Assisted by Mr. Dieudonné, I made the necessary alterations in the construction of the fire-hearth of this locomotive, so as to make it fit for being heated with mineral oil.

This was not a very easy task. For the combustion-chamber had to be simple in its construction, occupying as small a space as possible, and had to be constructed without brick walls or arches, which, in a machine so subject to violent concussions as a locomotive, would have involved serious dangers. Also the quantity of oil to be burnt hourly in a locomotive of 300-horse power is so considerable, and the space available for its combustion is comparatively so small, that the conditions under which the combustion has here to take place are entirely different from those existing in the preceding experiments. I solved the problem in the following manner:

1. I first experimented on a vertical grate, consisting of a row of upright bars, hollow, but open in front on the whole of their length, each grate-bar thus resembling an upright cast-iron channel. The oil is poured slowly from above into the interior of the bars, where it is evaporated by the heat existing in the fire-place. The vapors thus produced are burnt immediately in escaping from the bars, by the air which enters between the bars. The affluence of oil and air must be regulated in such a manner that the vapors burn without smoke, and that not more air is admitted than is necessary for the combustion. This condition is very important. For the principal advantage of the use of liquid fuel in regard to economy lies in the possibility of effecting a complete and perfect combustion by exact regulation, an advantage which liquid or gaseous fuel has over any kind of solid combustible.

2. The thicker and stronger the grate-bars, the better will their inside be protected against the cooling influence of the air, and the more rapid will be the evaporation of the oil. The thickness in cast-iron of the bars has to be found by experiment for each kind of oil. It must be such that the oil, in running down along the interior walls of the bars, is entirely evaporated before it reaches the lower end of the bars.

The combustion effected by this grate produces a lively, but very short flame, only one-fourth of a metre in length. At a greater distance than this the gases are invisible, though very hot, as is proved by the immediate incandescence of a strong platinum-wire, when held into them. This seems to show that the completeness of the combustion, and consequently the absence of all carbon, is the cause of the invisibility of these gases. They may in this respect be compared to the exterior part of the flame produced by a blow-pipe.

3. Whenever it is desirable to increase the surface on which the oil is evaporated, without increasing the size of the apparatus, the grate has to be laid down in an inclined position. Thus the oil has to run a longer distance, and the quantity of oil evaporated during a certain time is more considerable. The draught of the stack has then to be augmented in proportion to the greater vivacity of the combustion, so as to make the latter complete and perfect.

This kind of apparatus has to be adopted for heating locomotives with liquid fuel; the grate may be placed in an inclined position into the ash-pit. The bottom of the apparatus may be made of copper, hollow, and filled with water or arranged in such a manner as to form a part of the boiler. It is in this case advantageous to give the whole apparatus the shape of a cylinder, to avoid all even surfaces as well as all stay-bolts in the interior of the fire-box. The oil enters through a number of holes provided in the upper part of the grate; it then runs down over the grate, at the lower end of which a cast-iron projection prevents that part of the oil which might not have been evaporated from coming in contact with the bottom. The locomotive No. 291, which I used in my experiments, did not have so perfect an apparatus, not being specially constructed for this purpose. The grate had there to be placed in front of the ash-pit. The latter was closed by an iron plate, which was covered and protected by a

brick plate. The iron frame below the fire-bridge had to be protected by a brick mantle resting on an arch of fire-brick. This temporary arrangement stood very well in the trials, and was not in the least affected either by the heat in the hearth, or by the shaking of the engine, although the bricks were not of superior quality, and although the engine moved at a speed of 60 to 70 kilometres (=37 to 43 English miles) per hour. The distribution of the oil over the grate is regulated by a single graduated cock. Mr. Brisse, second director of the railroad machine-shop at Epernay, has replaced this cock by a quite simple apparatus, of which, however, I am not allowed to publish a detailed description. The principal feature is a screw with a graduated head, placed within the reach of the engine-driver.

The draught in the chimney is effected in the ordinary way by the action of the blow-off pipe.

Whenever mineral oil is used in the right way, neither smoke nor cinders are produced. When the locomotive runs at a high speed, the draught effected by the blow-off pipe is so strong, that the consumption of oil, and consequently the production of steam, can be increased at pleasure without creating any smoke.

The regulation of this fire by means of a simple cock, is so easy a work that it can be done by the engineer in addition to his other duties. The appearance of the gases which escape from the chimney, serves as a guide in this operation. The gases must have a slight yellowish tint, which shows that they do not contain an excess of air.

A self-acting mechanism can be applied to the cock to prevent all fatal consequences which might arise from a sudden and vehement concussion produced by some accident. This mechanism would shut the cock and extinguish the fire at once, thus rendering a conflagration impossible, which has often originated under such circumstances and proved highly disastrous with locomotives heated by coal.

I must here remark that only the heavy and thick-flowing kinds of mineral oil or petroleum, which are less inflammable, can be used to advantage for heating locomotives. The oil is tested by being heated to 100° Celsé, after which a well-lit link is dipped into it. If the oil is of the proper kind, the link will not set fire to the oil, but will itself be put out.

Numerous experiments were made with the above-described heating system on the French Eastern Railroad. They were conducted by Mr. Dieudonné, who afterwards communicated to me the following tables and remarks on the results obtained:

DATE.	Number of Wagons.	Gradient, Rise per 1 Metre	Average Velocity.	Total Distance.	Consum'tn of Oil per Kil're.	Weight of the Wagons.	REMARKS.
		Millimetres.	Metres p. min.	Kilometres	Kilograms	Kilograms	
July 19...	8	0	60	18	4.70	50,000	Pretty good weather.
July 30...	8	0	60	18	4.58	50,000	Pretty good weather.
July 30...	11	0	60	18	4.71	90,000	Fine weather.
Nov. 26...	4	3.5	60	55	4.70	30,000	Very bad weather.

1 Metre=39.38 inches Eng.
1 Millimetre=.039 inches Eng.
1 Kilometre=3281 feet Eng.
1 Kilogram=2.2 lbs. avvir.

The locomotive used in these trials had but one driving axle and weighed 20,000 kilograms. Weight on the driving axle, 8400 kilograms. Size of heating surface, 60 square metres.

The best results were obtained on the 30th of July, when the engine developed about 250-horse power, or 4½-horse power per square metre of heating surface. This result is certainly very satisfactory.

The firing-up of the engine takes 75 min., when the blow-off pipe of another engine is used for the purpose. If the engine has to be heated up exclusively by

the draught of its own chimney, 3½ hours are necessary. The firing up of an ordinary engine with coal requires 2½ to 3 hours.

THE SUEZ CANAL.

The whole of the land acquired by the Suez Canal Company, between the Mediterranean and Red Sea, for the works of construction and maintenance, amounts to 39¾ square miles, and about 37 square miles were required for the construction of the fresh water canal. The former area was apportioned by the Egyptian Convention of February, 1866, in the following manner:

	ACRES.
Port Said	1062.50
From Port Said to El Ferdane	5831.50
Raz-el-Ech	37.00
Kantara	158.00
From El Ferdane to Lake Timsah	4003.00
Ismailia, on Lake Timsah	2854.00
From Lake Timsah to the Bitter Lakes	4200.75
Across the Bitter Lakes	3508.85
From the Bitter Lakes to the Lagunes of Suez	1927.40
Across the Lagunes of Suez	889.50
Port of Suez	889.50

By the original concession the powers of the Canal Company were not restricted to this area; but they were definitely settled by Napoleon in April, 1864, when, in his character of Imperial referee, he adjusted the difficulties which had arisen between the Egyptian Government and the Company. By that decree he awarded an indemnity of £3,360,000 to be gradually paid by the Egyptian Government in instalments, commencing on the 1st of November, 1864, and expiring November 1st, 1879; the sum of £1,520,000 was to be paid as compensation for the substitution of European workmen for Egyptian laborers, and the increased dredging plant; £1,200,000 for the abandonment of certain land rights granted under the concession of 1856, in repayment for the sums expended and works done upon the fresh-water canal; £400,000 and £240,000 as payments in full of all rights to duties levied upon the fresh-water canal.

According to the published accounts of the Company, the total amount raised for the works since the opening of the subscription in France in November, 1858, has been £18,066,265, and the total expenses, including works, material, and plant, the purchase of certain lands, the financial, engineering, and general administration, has amounted to £16,174,933, leaving a balance in hand, between the actual outlay and the subscribed capital, of £1,891,332—a sum chiefly made up by £1,189,781, the concession of the Egyptian Government, and £680,000 of cash in hand at Alexandria and Paris.

The details of the gross realized capital may be briefly collected as follows:

Shareholders' capital	£8,000,000
Sale of bonds	3,999,996
Egyptian Convention	1,189,781
Imperial arbitration	3,360,000
Rates of exchange	258,852
Various receipts realized by the Comp'y	1,257,636
	£18,066,265

The summary of the expenditure account stands thus:

General expenses of preliminary arrangements, survey, etc., from 1854 to 1859	£3,165,705
General expenses of administration and negotiation between France and Egypt	678,449
Sanitary service, 1868, 1869	24,282
Telegraph service, 1868, 1869	6,800
Transport service, boats, rolling stock, buildings, etc	324,887
Payments to contractors for materials	688.557
Dredging machines and heavy plant	1,363,848
Workshops	168,830
Works of construction, canals and ports	8,706,866
Miscellaneous	278,499
Expenses of various branches of the Company's management	768,210
	£16,174 933

So that the actual amount expended upon the canal has been £161,749.34 per mile. This amount, of course, represents the total outlay, from which have to be deducted the sums to be realized by the sale of plant, the Egyptian concession, the indemnity award, and, to arrive at the actual cost of construction, the expenses of management, a total of £9,394,938 to be deducted from the £16,174,934, leaving £6,779,996 as the total cost of construction up to the end of June last, the balance in hand being then, as we have seen, £1,891,332; and, assuming that this balance was found sufficient to complete the works, the actual cost per mile of the

canal proper will have been £8,671,328, exclusive of administration, etc.

Now that the long and tedious work is finished, it is but natural that the acclamations which greet the successful severance of the Isthmus should occupy the universal breath, and that admiration of the work should absorb all public thought. But a few weeks, however, and the Suez Canal will be no longer universally regarded as a modern wonder of the world, but as a commercial and maritime convenience, and what is now gazed upon as marvellous will soon become common-place. Then all the doubts which have been current, and strengthened by the unfortunate grounding of vessels on the inauguration day, will have been scattered or confirmed; we have M. de Lesseps' assurance that all the fears occasioned by those *contretemps* are groundless; but a short experience of the practical working of the canal will refute or establish theories, and it will be interesting to watch whether the sand-banks, as prophesied by alarmists, will stop the navigation; if the harbor of Port Said will silt up, and the canal become choked, or its banks destroyed. And the time that is needed to test the engineering success of the work will also prove sufficient to establish its commercial prosperity or failure. The competition and advancement of trade seem alike to forbid the latter; and not the canal alone, but the Mediterranean ports also, will share the advantages of the trade it has diverted. The following table, compiled by M. de Lesseps, shows the saving of distances which will be effected by the adoption of the Isthmus route, Bombay being taken as the converging point:

Distances.

European and American Ports.	By the Cape.	By the Canal.	Saving Effected.
	miles.	miles.	miles.
Constantinople	14,760	4,350	10,410
Malta	14,130	4,990	9,140
Trieste	14,420	5,660	8,760
Marseilles	13,675	5,745	7,930
Cadiz	12,584	5,384	7,200
Lisbon	12,950	6,050	6,900
Bordeaux	13,670	6,770	6,900
Havre	14,030	6,830	7,200
London	14,400	7,500	6,900
Liverpool	14,280	7,380	6,900
Amsterdam	14,400	7,500	8,900
St. Petersburg	15,850	8,950	6,900
New York	15,000	9,100	5,900
New Orleans	15,600	9,000	6,600

The average distance being reduced one-half *via* the now route.

Even before its completion the Suez Canal was pressed into the service of transporting goods to the utmost of its capacity, and up to the 30th of June last, £136,865 has been realized by tolls. Already, for six years the harbor of Port Said had been a resort for ships. In 1863, 295 ships, collectively of 48,759 tons, had called there. From the 1st of June, 1867, to the 15th of April, 1868, 1,000 vessels, representing 232,000 tons, had entered Port Said—a number which increased during the following year to 1,362 ships, collectively of 637,440 tons. At this present time Port Said forms a depot for no less than seven steam navigation companies—the Messageries Impériales, the Society-General of Steam Transport, the Marc Fraissinet Company of Marseilles, the Bazin Company, the Russian Company of Navigation and Commerce, a Spanish Steamship Company, the Austrian Lloyds; and an American Company is about to be established with a capital of £6,000,000 with the Mediterranean ports as depots, and trading thence to India and China; while we are of course building vessels specially designed for the new route.

With so much activity, and with hope of so vast a diversion of trade towards the canal, the prospects of the Mediterranean ports are especially flourishing. Marseilles of course will reap the greatest advantage, but all the other towns upon the coast will profit by the benefit of a newly-created trade, or will awake to win back the positions they once held.

THE FRENCH are making arrangements in good time for observing the transits of Venus, which will take place in the years 1874 and 1882. The event is one of considerable interest and value to scientific men, and it is therefore desirable that it should be viewed from those parts of the earth's surface where it can be best observed. The stations fixed upon for 1874, are Oahu (one of the Sandwich Islands), Kerguelen Island (in the Indian Ocean), Rodriguez (a dependency of the Mauritius), Auckland (New Zealand), and Alexandria.

THE directors of the Edinburgh School of Arts have agreed to allow female students to attend its lectures and classes.

RESEARCHES UPON THE STRENGTH OF MATERIALS EMPLOYED IN MODERN SYSTEMS OF BUILDING.

From "The Builder."

We are in receipt of the second and concluding volume of Mr. Bindon Stoney's work on strains in girders and similar structures.*

The work, in its complete form, appears likely to prove so important a contribution towards the elucidation of the science and practice of construction, that we are inclined to consider that the present volume, from the elements of which it treats, puts forward claims to somewhat fuller notice.

Although so long an interval may be regarded by some to have elapsed before the appearance of the concluding portion of the work, when the wide range of authorities to which the author has had occasion to make reference is noted, and the nature of the inquiries incident to such a work is borne in mind, it will no doubt be admitted that time would be necessarily occupied in the production of such a volume as that which is now before us.

It appears at an opportune moment, as a want has long been asserting itself, no less on the part of the general public than in professional circles, with reference to the comparative safety and durability, as well as cost, of modern engineering and architectural erections.

More particularly may this, perhaps, be said to be the case in regard to compound structures in which iron and other materials may have been extensively employed.

A theory has sprung up of late years which has been by many considered favorable to the application of iron to building purposes largely in conjunction with the ordinary practices of architecture. Since the introduction of this system, however, the theory of construction itself would appear to have become so widened by successive changes in the manufacture and preparation of building materials, more especially of lately added elements, that former investigations into the strength and properties of materials, have in some instances become more or less valueless and inapplicable. Unlike a somewhat similar treatise to that which is now under consideration, which was issued by Mr. Clark, and founded upon the construction of the Conway and Britannia tubular bridges, the conclusions which have been arrived at by the author of the present volumes are not alone based upon such features as might have been observable during the erection of any particular undertaking, but in addition embrace the opinions of many well-known authorities who have treated of some of the questions which are involved. The treatise upon the Anglesea and Carnarvon Bridges has long been regarded as an authority of rank, owing to the circumstance that many of the assertions which it embodies could be referred to actual experiments which were necessitated in carrying out the undertakings of which the work treats. The value of Mr. Stoney's work, independently considered, may be inferred, when it is remembered that in a single span of 460 ft. of the Tubular Girder Bridge, between Holyhead and Anglesea, no less a quantity than 3,000 tons of material is employed, while in other structures which serve a like purpose, the desired objects have been accomplished with less. Notably we would refer to the late Mr. Roebling's bridge over the Niagara Falls, in America—a structure which is, as well known, used for purposes of locomotive passenger and goods traffic, and yet comprises within a single span of 820 ft. only 1,000 tons of materials, and of this quantity more than one half is timber. The scope which, by such a contrast alone, would seem to be afforded for a more economical adaptation of material than that which obtains in English practice, might be considered to justify the researches into which Mr. Stoney has been led in these volumes, and we would have been far more displeased to have observed a reference to the comparative cost, style, and weight of such undertakings as executed in England and elsewhere, notwithstanding the prejudicial

* The Theory of Strains in Girders and similar Structures; with Observations on the Application of Theory to Practice, and Tables of the Strength and other Properties of Materials. By Bindon B. Stoney, B. A., Member of the Institution of Civil Engineers, and Engineer to the Dublin Port and Docks Board. In 2 Volumes, with Illustrations. London: Longmans, Greene & Co. 1869.

reflections to which such an inquiry might be calculated to give rise.

The question of the weight of materials demanded in the erection of bridges was, we believe, first sought to be experimentally realized in this country by Mr. Peter Barlow, whose standard investigations upon the strength of materials are frequently referred to in the present volumes. Although, contrary to the predictions of the moment, considerable success has attended the erection of the Niagara Railway Suspension Bridge, the system upon which it is constructed would not appear to have largely recommended itself for adoption. Numerous costly railway bridges have recently been erected over the river Thames, and in some instances the question of level has, at great additional cost, been seen to have been subordinated to the requirements of an arch structure. A more extensive application of the Niagara Bridge system has been lately employed in the designs of a grand bridge over one of the American rivers, and we believe that it has long been an object, on the part of Mr. Peter Barlow, to introduce a somewhat similar class of suspension bridge into the domain of engineering science in this country. It is well known that the present Lambeth Bridge embodies a most important series of investigations as to the cost and stability of bridge accomodation, and that Mr. Barlow made a special journeyto inspect the Niagara structure before this experiment was attempted. The longitudinal stiffening of the Lambeth Bridge is of iron, while in Mr. Roebling's design it is of wood. The question as to the desired rigidity in such structures mainly resolves itself into the dependence which may be placed upon the nature of the materials to be employed. Prior to the application of iron in the form of wire cables in suspension structures, it is well known that English engineers regarded with much diffidence the continuity of certain qualities in iron throughout great lengths, either in the form of girders, suspension links, or laminated bands. This doubt yet largely prevails, and some important evidence is adduced in reference to these points by Mr. Stoney, which is likely to engage considerable attention in the professions of engineering and architecture.

We are led to infer that the author is in accord in a certain measure with Mr. Barlow as to the magnitude of practicable spans upon the suspension principle, and that this object would be chiefly likely to be attained where the inherent defects attending the application of iron in ordinary forms may be avoided. So far, up to the present moment, the economical appliance of iron in the erection of bridges of large span would appear to be discovered in cases where that material has been employed in the form of continuous twisted wire ropes. In view of the future erection of any large railway bridge, say, for instance, over the Mersey, uniting Liverpool and Birkenhead, a project which has been long contemplated; or, in the event of the necessity arising for the maintenance of the connection between Holyhead and Anglesea, should the existing means fail, the practicability of the suspension system as seen to be successfully carried out in America, will necessarily claim further attention and research.

Mr. Stoney's reference to the experiments of Mr. Kirkaldy, which are given in a valuable tabulated form in the body of the work, are in no way calculated to reassure us as to the advantages which would be likely to attend a too unguarded employment of iron and cognate materials in architecture. It has been demonstrated that regard must be paid to architectural requirements in cases where iron may be proposed to be employed as an auxiliary material, and many results tend to prove that in this respect the tentative science of engineering must be held subordinate to the better founded and established laws of architecture.

Mr. Stoney observes that when an imperfectly elastic material has received a permanent set from the application of any weight, which is subsequently removed, the material becomes more perfectly elastic than before, within the range of strain which first produced the set, and its alteration of length per unit of strain is less than at first. For practical purposes the author asserts that the limits of elasticity in wrought-iron does not exceed 12 tons per square inch; and though higher strains than this may not in the least diminish its ultimate strength, yet they will take the stretch out of it, and this may render iron which was originally tough and ductile so hard and brittle as to be seriously injured for many purposes. It is, in our opinion, to the injudicious tests to which iron is

occasionally subjected, that many cases of rupture may be attributed in that material, and possibly many instances of disastrous boiler explosion. The extreme facility with which the tensile strain and compressive resistance of iron may be regulated has almost rendered the employment of that material at length dangerous, especially in conjunction with materials of dissimilar properties.

Iron may be made to pass through so many grades of deterioration in its manufacture without readily indicating the processes to which it may have been subjected without actual strain or fracture, that the tendency of home and foreign competition, coupled with the facilities to which we have referred, has resulted in bringing the production of that article in England in some directions to a discreditable level. It would appear that the tensile properties of iron may be retained over a wider range of cheap contamination than some of its other properties, and many of the qualities of iron now usefully employed in building are imported from abroad.

We notice with interest that in connection with the theory of strains in girders and similar structures the imperfections which are most commonly to be met with in the materials which are adverted to, are viewed with that importance which this branch of the subject deserves. There could not, perhaps it may be said, be found in any publication extant a more masterly exposition of the general properties of iron than is to be met with in this volume. No review of a work of this kind could probably do full justice to its contents, for being mainly intended for the instruction of engineering students, and for guidance in the varied elements of constructive science, it would be attended with difficulty to single out for especial remark any particular branch of which it treats. We do not remember, however, in any similar work which has come under our notice, to have observed the question of connections in iron so treated of as in some portions of the later volume, more particularly under the heading of "Appliances for Connecting Iron Work," pages 351 to 370. A perusal of the first 265 pages of vol. ii. would well repay the attention of architects and builders, being composed more particularly of a treatise on compressive resistance in bodies of brick-work, stone, iron, and various classes of cements, as well as including the action of cements and builders' materials under tensile and lateral strains. This feature of the work, in view of the recent incident at the Holborn Valley Viaduct, is entitled to especial attention.

Quoting some experiments of Mr. Clark, in relation to the action of stone under compression, the author says that in the instance which he refers to, "the sandstones gave way very suddenly, and without any previous cracking or warning. After fracture, the upper portion generally retained the form of an inverted square pyramid, very symmetrical, the sides bulging away in pieces all round. The limestone formed perpendicular cracks and splinters a considerable time before they crushed."

It will be borne in mind by many that this description represents very nearly the order in which the fractures in the Farringdon Street columns would seem to have been generated. We hope, however, these are not so extensive in the mass as might be inferred from the external appearance of the columns. Continuing from this portion of the work, Mr. Rennie observes: "It is a curious fact, in the rupture of amorphous stones, that pyramids are formed, having for their base the upper side of the cube next the lever, the action of which displaces the sides of the cube precisely as if a wedge had operated between."

The features which have presented themselves in the visible lines of fracture upon the polished facets of the Holborn Viaduct column, appear so to approximate to what might have been anticipated from the experiments which are described in this portion of Mr. Stoney's work on the theory of strains, that we view the occurrence with a regret which no assurance with which we have yet been inspired has diminished to the extent that could be wished.

The importance of such a treatise as that which Mr. Stoney has at length produced, in the hands of the pupils of modern engineering and architectural establishments, cannot well be overrated.

In concluding the observations which we have been led to make upon the perusal of the work, we would note the singular lucidity of the arrangement of the letter-press, and the novelty of the illustrations which is displayed. As an ex-

ample of the clearness and simplicity for immediate reference with which works of a similar character may be contrived, it may claim to possess several features well worthy of imitation.

Mr. Stoney's work lends a ready key to the more abstruse elements and problems of constructive science; and it is sufficient to bear in mind the length of time over which the author's labors have extended in its production, to reach the conclusion that the work may have been written with other objects than those of pecuniary gain or contemporary praise.

It cannot fail to be regarded as a valuable accession to the literature of applied arts and sciences, and in its more especial direction should take a foremost rank.

SOMETHING ABOUT BELLS.

From "The Century."

The largest bell in the world is in Moscow—the City of Bells. It was cast by order of the Empress Anne, in 1653; is 21 ft. 4½ in. in height, 22 ft. 5½ in. in diameter where the clapper strikes, and is believed to weigh from 360,000 to 440,000 lbs. Historians are in doubt whether this giant among bells was ever hung. Dr. Clark, who saw it about the year 1801, says, in his "Travels," "The Russians might as well have attempted to suspend a line-of-battle ship with all its stores and guns." Bayard Taylor, on the other hand, maintains that it was both hung and rung, "it being struck by the clapper," as Korb says in his diary, "fifty men pulling upon it, one half upon each side."

In 1837, the Czar Nicholas caused it to be disinterred from its bed of sand, where it is supposed it was lodged during the conflagration of 1737, and placed it on the granite pedestal where it now rests. It was then consecrated as a chapel, the entrance to the interior being through a large fracture near the mouth, the cause of which is also a subject of controversy.

It is recorded that at the casting of this bell, nobles were present from all parts of Europe, who vied with each other in the value of the gold and silver plate, jewelry, and other votive offerings which they cast into the furnace. It is doubtless owing to this practice, which prevailed in olden times, that the existing notion is derived that ancient bells are of better material than the modern ones, on account of the silver in their composition. It may be added, however, that the idea is incorrect, since recent experiments have shown that its introduction causes a positive deterioration of the resonant quality of bell metal. Whoever has been in Russia recalls as chief among his memories the sounds of the great bells which form a part of religious worship, and are regarded by the Russians with superstitious veneration. In Moscow alone there are five thousand, and when they unite on festive occasions in one mighty chime, the effect, especially at a distance, is said to be majestically grand.

There is now suspended in the tower of St. Ivan, at Moscow, a bell which weighs 144,000 lbs., and the diameter of which is 13 ft. It is said that when it sounds, which is but once a year, "a deep, hollow murmur vibrates all over Moscow, like the fullest notes of a vast organ or the rolling of distant thunder."

The bell of Notre Dame Cathedral, at Paris, cast in 1680, weighs 30,000 lbs.; that of St. Peter's, at Rome, weighs 17,000 lbs.; that of Notre Dame Cathedral, Montreal—the largest in America—29,000 lbs.; and that of the Parliament House, in London, 30,000 lbs. When it is remembered that the largest bells heard in our American cities rarely weigh more than 3,000 or 4,000 lbs., some idea may had of the volume of tone which belongs to the monster bells above described.

The Chinese have likewise produced bells of colossal size, one of which, at Pekin, weighs 120,000 lbs., but the tone of their bells is said to be discordant and "panny" like that of their gongs."

The most remarkable fact in connection with the mortality of Bombay is that more than one-half of the total casualties are casued by zymotic diseases of the miasmatic order—that is to say, are consequent on defective drainage, impure water, absence of ventilation, and the unclean habits of the community.

UNDER THE THAMES.

From "The Building News."

In March of the year 1843, the first passage under the Thames was opened to the public by the celebrated engineer, Isambard Brunel; in a few weeks a second sub-way was opened by Mr. Barlow. Separated by an interval of 26 years, passing under the same river at points not widely apart, it may be instructive to "compare notes" on the two.

"*The* Thames Tunnel" has for long been one of the wonders of childhood, a leading attraction in pictorial exhibitions, and from its subterranean depths many a toy has been carried into far-off country villages as a memento of a visit to the great metropolis. These associations have thrown around Brunel's great work a sort of halo which Mr. Barlow's tube will never achieve. Our purpose, however, lies with the constructive peculiarities of the two kindred, yet unlike, works. It must not be supposed that no attempt had been made, prior to the time of Brunel, to pass the Thames by a tunnel; on the contrary, we find that a company called the Thames Archway Company commenced a tunnel so far back as 1804, and did, indeed, penetrate the bed of the river for a distance of 1,040 feet. Unfortunately, a very high tide put a stop to their labors, as a violent inrush of water filled the tunnel. After some attempts to raise capital to pump out the water, the whole scheme was abandoned. This tunnel was to have led from Rotherhithe to Limehouse. Even so far back as 1799, a tunnel was talked of between Tilbury and Gravesend.

The following are the salient points in the history of Brunnel's tunnel. The plans were completed in 1823, and the works commenced in 1824. The great mistake made in this first tunnel was in carrying the heading too near to the water of the river; in fact, sometimes not more than 4 ft. intervened between the tunnel and the water. Great, almost insurmountable difficulties were thus encountered. During the progress of the work a stoppage of seven years occurred through an irruption of the river. After incessant care, and the exercise of great engineering skill, Brunel completed his great work in 1843. Thus 19 years elapsed between the commencement and finish of this work, which even now stands unrivalled in the solidity of its construction. Deducting the 7 years during which the works were suspended, it will be seen that 12 were really spent in its completion. As its construction was difficult, so was it also costly, the total expenditure being about £450,000. As is well known, the sub-way which Brunel thus made has been purchased for purposes of metropolitan railway extension. Ere long two lines of rails will traverse its massive arches. Thus, in this final adoption of his great work, has Brunel the Elder been proved to have been right, but before his time; just as his yet more famous son has triumphed over those who scoffed at the "Great Eastern" as a useless monster, little dreaming of the work she was to do in joining far distant lands together by magic electric bonds of union. Turning now from the massive elliptical brick-work of Brunel, with its two 14 ft. archways passing, as it were, along the foci of its length, let us look at the no less wonderful work of Mr. Barlow. As Brunel's work was marvellous for its vast solidity and the many difficulties overcome in its construction, so is Mr. Barlow's subway wonderful for its cheapness and the ease and rapidity with which it has been executed. On the 16th of February, 1824, Brunel commenced his tunnel, and finished it in March, 1843. Just 45 years later, on the 16th of February, 1869, was the present sub-way started, and it will be opened in November, thus taking nine months to complete. The estimate for its construction was £16,000, and the cost will, in fact, most probably be under this sum. Of course, in comparing the cost of this present work with that of Brunel's, the very great difference in magnitude must be borne in mind. The dimensions of Mr. Barlow's tube are as follows: The diameter of the tube is 7 ft., and its total length will be 1,320 ft., of which 1,110 are finished; its material is cast-iron. This cast-iron is disposed in segments, each reaching 18 inches along the tunnel, and nearly ¼ round it, and weighing about 4 cwt. each. At the top a key is inserted to tighten the segments into their places.

These keys weigh about 1 cwt. each. The joints are made with strips of white pine between the longitudinal flanges, and with tow in the circular ones. The tunnel is cut through the London clay at such a depth that at no spot does the river water come within 22 ft. of the tube. That there should any injury arise to the tube from the action of water is very unlikely, as not only is the clay so free from water that every drop required for the work has to be sent down the shaft on Tower-hill, but a coating of lias cement is being forced in around the tube by pumping. To admit of this being done, a space of 1 in. is left all round the tube by cutting the heading through the clay that much larger than the tube itself. One very remarkable fact in connection with this tunnel is the great distinctness with which sounds reach it from the river overhead. The passage of steamers up and down the river is distinctly audible in the sound of the paddles and screws; nay, sometime back, Mr. Barlow was fetched in a great hurry to see what was the matter, because a sound as of rushing water was plainly heard. On examination this sound, which had so alarmed those working in the tunnel, was found to be caused by a large steamer in the river blowing off her spare steam. Recently a steamboat exploded near the Tower Wharf, and, strange though it may seem, not only was the explosion audible, but its effects could be plainly felt in every part of the tunnel. At the present time it is rather sultry at the end of the tunnel near the shield, as all the air has to be driven in by a fan in the shaft, and a good deal of warmth is naturally produced by the men at work and the candles needed for their use. So soon, however, as air is reached at the Tooly street side, all will be cool enough. On the completion of the tube, rails of 2 ft. 6 in. gauge will be laid in it, and upon these rails omnibuses of iron will be run. These omnibuses will be 10 ft. 6 in. long, 5 ft. 3 in. wide, and 5 ft. 11 in. high. At the bottom of the shaft at each side of the river will be provided ropes, driven by stationary engines. These ropes are to give the buses a start of about a hundred feet down the incline. After this impetus the vehicle will descend the rest of the incline and ascend the opposite one without further application of power to it, except from the effects of gravity in the first half of its transit. Up and down the shafts the passengers are to be taken by means of lifts. Mr. Barlow estimates that not quite three minutes will be requisite for each transit, including the raising and lowering of the lifts. Allowing, therefore, 14 persons to each journey, and 16 hours to each working day, upwards of 4,400 passengers per day can be carried. If requisite, two omnibuses can be joined together, or one of double or treble capacity used, so that a very large traffic can be accommodated. There seems to be little doubt, therefore, that the tunnel will turn out a very good thing for the shareholders, paying them very large dividends. The continuous and heavy traffic over the many bridges across the Thames has reached dimensions by no means convenient to those who have to pass them. Notably the traffic over London Bridge has so overtaxed that venerable viaduct as to render it highly dangerous to her Majesty's lieges, and to call forth the proposition to carry out excrescent footways on cantilevers and brackets, to the everlasting disfigurement of the noble pile of granite.

On the success or non-success of Mr. Barlow's under-river omnibuses turns a very important question. The great test will be in the return that the shareholders will get for their money. If their dividends are large, two things will be proved —namely, that tunnels beneath rivers can be made at a sufficiently small cost to pay, and also that they supply—in crowded localities, where navigation claims the stream—a public want. To prove that the public needs them, and that they can be reasonably constructed, so far as cost goes, means to stimulate their construction in many localities besides the metropolis. We may expect during the next year or two to hear of a good many schemes for going *under*, rather than *over*, rivers. Naturally enough, some of these tunnels will be made in places where a sufficient traffic cannot be got to make them remunerative; but, on the average, the public will benefit more than it will lose. To argue in the present day in favor of good means of communication would be like stepping back half a century to commence the race of life; yet it is by no means a superfluous observation to say that our facilities for easy and swift transit are by no means what they might be, and what we trust they shortly will be. To all of

us time is generally the equivalent of money, and people are often more fatigued in going to and returning from some business than by the work itself. Never before did such a need of cheap, quick transit for our working classes, the busy bees of our great hives, exist. Mr. Barlow and others, therefore, who seek to supply the means, deserve every encouragement.—*Palmam qui meruit ferat.*

MODES OF MURAL DECORATIONS.

From "The Builder."

A technical work of much value has just appeared from the pen of Mr. W. Cave Thomas, on the subject of mural decorations, evidently the result of much thought and labor.*

One of the author's leading theories is, that art should endeavor to depict or model perfect humanity; and that education should endeavor to make this ideal, ultimately, a living fact. He says at the onset, pertinently, that he cannot understand why poets and painters should wish to infer that their "inspiration" is independent of rules and science; for order being Heaven's first law, it must be certain that no success can be achieved that is not the result of, either consciously or unconsciously, working in accordance with scientific principles. Thus pronouncing himself in the ranks of order and moderation, as he has done before in other works from his pen, Mr. Thomas proceeds to state the antiquity of mural painting as the earliest form of pictorial art, and its value as a memorial of national existence, and of the aspirations of that existence. Michael Angelo spoke of easel painting as an occupation fit for women, compared with mural painting; and Mr. Thomas, like ourselves, follows in his wake as far as the highest appreciation of the last-mentioned branch takes him.

He treats of fresco painting first. Odd confusion has long existed as to the meaning of the word fresco; for people even now constantly speak of all pictorial mural decorations as frescoes; but, as most of our readers must be aware, the term properly applies only to those wall paintings that are executed by means of a particular process. Encaustic paintings, oil paintings, and water-glass paintings, are easily applied to walls; but that application does not constitute them frescoes. Although we are not going to give the details of the processes described by Mr. Thomas, which should be studied from his work, we may point out that frescoes are paintings made with colors simply mixed with water, upon fresh wet mortar. The necessity for newness in the mortar is so important, that only sufficient is placed upon the wall to enable the painter to execute the piece he has undertaken for one day's work. On the following morning, or whenever he resumes his task, another piece of wall is newly plastered, to admit of his operations. But it is within the limits we have set out for ourselves, to quote the nature of the preparations a wall should receive that is intended for frescoes. The Italian masters preferred this vehicle to any other, if we may consider their most frequent use of it a sign of preference; but, with the exception of the frescoes in the summer-house at Buckingham Palace, and those in the Houses of Parliament, there are scarcely a dozen examples of the process to be counted in this kingdom.

Mr. Thomas states that a brick wall, a brick or brick and a half in thickness, well dried, and of equal hardness, is the best kind of wall for the purpose. The use of laths is sometimes resorted to for special circumstances, but never when a dry brick wall is available. Outer walls, having a liability to damp, he would have lined with brick; and he records the suggestion of a detached inner wall, bound here and there to the outer one, without, however, quoting any actual experiment of this plan. Speaking now, out of our own experience, we should hesitate to adopt this last mode, having known the places where the junction is made between the two walls to be so many means of conducting the outer damp to the inner surface and spreading it in patches. Mr. Thomas objects to bat-

* Mural or Monumental Decoration; its Aims and Methods. Comprising Fresco, Encaustic, Water-glass, Mosaic, and Oil Painting. By W. Cave Thomas. London: Winsor and Newton, 38 Rathbone place.

tens and laths on account of their perishable qualities; but he mentions that many of the fine Italian ceilings are on lath and in good condition. He thus describes their construction:

"Most vaulted ceilings, in what is termed the *piano nobile*, or principal floor of every palace, are constructed of wood. The lathing in this case is not attached to single thin pieces of timber, cut to the shape of the ceiling, but to a strong grating; in some cases the ribs and transverse pieces of this grating are 4 in. thick each way. The lathing in Italy is a very peculiar process. The material is the reed, which is cultivated so extensively in that country, and used in so many ways. It grows to the length of about 18 ft., and is rather more than 1¼ in. in diameter at the base. When these reeds are used for lathing, they are split, and not being strong enough for the purpose, in this state, they are wattled upon the grating. The result of this somewhat complicated contrivance is a framework of great strength."

Assuming, however, that the surface intended for a fresco is a brick wall, the face of the bricks should be chipped, so as to enable them the better to hold the rough coat of mortar. This last requires to be applied with care, for if it be uneven, there will be patches of dust lying on every projection, and if the inequalities are filled up in the after coat, there will be cracks occurring between the thick and thin places. The tendency dust has to adhere even to a strictly perpendicular surface, has been taken into account, and a suggestion made that walls intended for frescoes should incline slightly forwards. The rough coat should be left to harden thoroughly before the next process is attempted. If the lime used in the mortar be fresh, two or three years will be required for it to attain the necessary condition. The quality of the lime is a matter, too, of the greatest moment in the next stage. The limestone used by the cinquecento artists was travertine, which is almost a pure carbonate of lime. Mr. Thomas gives the proportions as—

Carbonate of lime	99.4
Alumina with a trace of oxide of iron	.6
	100.0

While the lime used by the Genoese, which has resisted the effect of sea air for centuries, in a remarkable manner, yields:

Carbonate of lime	63
Carbonate of magnesia	36
Earthy matter, oxide of iron, and bituminous matter	1
	100

Nothing remains but to attend to the causticity of the lime, for if used too soon after being slaked, it blisters, and pictures executed without this proper precaution have flaked off, leaving, in the white patches exposed, all the effects of a snow storm. Some authorities aver that it should be kept for several years; some for three; some only for a few months. The German painter, Cornelius, prepared his lime for the frescoes in the Ludwig Kirche eight years before he used it; and an Italian writer of the sixteenth century, Leon Battista Alberti, speaks of a honey-like consistency gained by lime that had lain by for 500 years. But Mr. Thomas shows all that is requisite is that it should regain its maximum of carbonic acid. He adds that some degree of causticity is necessary to give the adhesive firmness required for induration; and is very precise in his details of preparation for both the rough cast and the upper coat, or *intonaco*, destined to receive the colors of the fresco. The implements, the colors, and the mode of operation, from the time the painter applies his tracing to the fresh mortar, till his day's work is glowing, finished, under his hand, are described minutely. No painter can need further instruction.

An important part of Mr. Thomas's book includes an exposition of the water-glass process, first discovered, or invented, at Munich, which many think may prove superior to all other modes of decoration. The information he publishes concerning it is a reprint, he has been permitted to give, of the pamphlet by Professor Fuchs, first translated from the German, printed and privately circulated, by command of the late Prince Consort. And this is supplemented by the report of Mr. Maclise on the process, and the correspondence that took place with German artists on the subject preparatory to its use in the Houses of Parliament. To those of our readers who are not acquainted with the nature of this composition, we may explain (though it has been before fully set forth in our pages), that there are four kinds of it—potash water-glass, soda water-glass, double water-glass, and fixing water-glass. The first is a mixture of fifteen parts of pul-

verized quartz, ten of well-pulverized potash, and one of powdered charcoal, mixed and exposed to a strong heat in a melting-pot till melted, when it is taken out, broken up, pulverized, and dissolved in about five parts of boiling water in an iron vessel; where it must be stirred and the water replaced as it evaporates, for three or four hours. This mixture, which is prepared with a care duly inculcated, when applied to surfaces has the property of rendering them compact, hard, and solid. Like glue, the Professor says, it may be employed for imparting solidity and greater cohesion to loose masses, for filling up cracks, and similar purposes. The other water-glasses have such differences in their ingredients as their names suggest, all of which are faithfully given and their effects described; and it is yet a matter of conjecture which will answer the purpose best. The chief purpose for which they are applicable and prized, is that of mural painting. They cause the colors to adhere well; and they give great durability, if not indestructibility, to them; and it is expected that when applied to existing frescoes they will prevent their further decay. But it is as a medium for new paintings that water-glass has raised the most sanguine expectations. As in frescoes, a coating of mortar cement is first applied to a wall intended to be covered with a painting, but before the *intonaco* is thought of this first coat has to be saturated with water-glass several times. When dry, the second coat is proceeded with, and in its turn impregnated with the same binding and cementing material. The German artists, Baron Kaulbach and M. Echter, who have done most for perfecting the application, find that the colors must be ground with pure water and the wall kept moist, whilst the artist is engaged upon it, by means of syringing it with water. Professor Fuchs applied water-glass to a stove-tile with some success; and the director of the telegraph-office at Munich has applied it to iron. A suggestion is thrown out, too, that plates of lithographic limestone might be used as a ground for water-glass paintings, which stone plates could be let into walls so as to appear to be part of them, and yet could be removed if necessary. In his list of mural decorations, Mr. Thomas mentions one painting executed with this material besides those in the Houses of Parliament—a procession subject, by Mr. Gambier Parry, at Coombe Abbey.

Touching mosaic, he speaks of the history of its revival by the Murano glass-blower, Lorenzo Radi, however, and its recognition by Dr. Salviati, of Venice. Its application in this country in the Wolsey Chapel, Albert Memorial, and Westminster Abbey, after designs by Mr. Clayton, is well known. But although France had a school for mosaic artists in Paris thirty or forty years ago, and Russia and Venice have now their rival manufactories, and Rome still encourages the art within the privileged precincts of the Vatican, there is little effort made in England out of South Kensington to further the use of this style of decoration. Two or three English writers have kept the subject before the public, and urged its advantages. Furthermore, Mr. Cole has a strong desire to create a taste for this kind of decoration, and Messrs Minton, Maw, Simpson, Rust, and others, produce ceramic tesseræ; hence it is probable that in a future edition Mr. Thomas may have to record that the art has taken root in this country. It is best applied in lofty spaces, such as vaults and domes of public buildings, where the limitations of its powers are least apparent; and needs caution and moderation in endeavoring to avoid both the meagreness of the earliest efforts and the redundance of the latest. It has but little of our author's sympathy, and he makes no effort to obtain for English art the honor of having made Abbot Ware's opus Alexandrinum in Westminster Abbey, though the substitution of Purbeck for cippolino, the usual groundwork, has led others to believe it was executed in this country.

After reading Mr. Thomas's book, we think of the great masters of old, not as the portraits of many of them show them, idle, clad in velvet and furs, with plumes in their caps; but in their equally pictorial blouses, pied with daubs of color, moving about on scaffolding, or ascending ladders, with their clever hands gritty, their speaking faces full of wonder, anxiety, and conjecture as to the result of the processes they are employing; and we feel that some of this uncertainty will be diminished for future painters by the care with which the various processes are described in it, and the fulness with which the result of many experiments are stated.

THE CHATELIER BRAKE.

Abstract from "The Engineer" and "Mechanics' Magazine."

The name of M. Le Chatelier has long been familiar to the engineering profession in connection with investigations bearing upon the economic working of the locomotive engine and other important matters. He now comes before us as the practical exponent of a principle which has received attention for some years past at the hands of several engineers. This is no less than enabling the driver of a locomotive, when reversing steam, to utilize the work done during the inverted action of the engine for regulating and checking the speed of trains. In other words, M. Le Chatelier has perfected a steam brake, and, although it comes to us as a novelty, it has already been applied to nearly 3,000 locomotives on the continent. With regard to the attempts which have from time to time been made to effect this object, we may first mention that in France M. Beugniot and in Austria M. Zeh have experimented with closed exhaust nozzles; the one so as to cause a vacuum behind the piston, the other to establish a pressure behind the piston, and thus avoid drawing in the heated gases of combustion from the smoke-box. Early in 1865 Mr. De Bergue experimented with a system of brake by compressed air, so arranged as to prevent the introduction of the fixed gases into the boiler. This system gave satisfactory results for short runs of two or three minutes, but did not answer when the action was prolonged. In July, 1865, M. Le Chatelier directed experiments to be made on this important subject on an entirely new principle, and his ideas have been put in practice with complete success both in France, Spain, and Germany.

In ordinary locomotive engines, when the valve gear is reversed while running forwards, for obtaining in an emergency the retarding effect of the full boiler pressure opposing the motion of the pistons, the reversed working cannot be continued longer than a few minutes without serious injury, owing to the heating of the cylinders and the cutting of the rubbing surface from want of lubrication; the cylinders act as pumps in the reversed working, drawing in the heated gases from the smoke-box and forcing them into the boiler. The object of the present plan is to enable locomotives, in taking trains down inclines, to be worked continuously for any length of time with the valve gear reversed, so as to obtain the advantage of the counter-pressure steam as a retarding power, instead of the train brakes, without involving the objections hitherto preventing the use of continuous reversed working. In the regular working of locomotives, not reversed, the piston in its forward stroke is propelled by the full pressure of steam from the boiler, until the steam is cut off by the slide-valve, after which the propelling power is continued through the remainder of the stroke by the steam expanding in the cylinder. But in the reversed working the distribution of steam is effected by the slide-valve in the inverse order and on the opposite side of the piston, while the motion of the piston and driving wheels still continues in the same direction as previously; in the first portion of the stroke, therefore, the cylinder is open to the exhaust on the front side of the piston, but in the latter portion the steam, at full boiler pressure, is admitted, and opposes the forward motion of the piston. In the return stroke the front of the piston, in ordinary working, is in communication with the exhaust until nearly the end of the stroke; but in the reversed working it is to the back of the piston that the exhaust is open, and the piston accordingly draws in the heated gases from the smoke-box at atmospheric pressure, and in the next forward stroke the contents of the cylinder are compressed as soon as the exhaust port closes, and forced by the piston into the boiler against the full pressure of steam. The latter portion of each stroke of the piston is thus made against the full boiler pressure, which resists the motion of the piston, and consequently acts as a powerful retarding force to check the rotation of the wheels in the direction of running.

The simple and efficient plan designed and carried out by M. Le Chatelier for counter-pressure working consists in introducing a small jet of hot water from the boiler into the base of the blast-pipe

of the exhaust port of the cylinder ; this jet being discharged at boiler pressure into the atmospheric pressure of the exhaust passages, the greater portion of the water instantly flashes into steam at atmospheric pressure, and instead of the heated gases from the smoke-box, a moist vapor or fog is now drawn into the cylinder behind the piston. The rubbing surfaces are thus maintained constantly lubricated by the presence of saturated steam, and all heating or cutting is entirely prevented. The jet of water is regulated so as to be always slightly in excess of the precise quantity required, the object being to prevent the possibility of drawing in any of the heated gases from the smoke-box ; and the constant escape of a slight cloud of steam from the chimney affords an indication to the driver of the sufficiency of the jet. Mixed jets of hot water and steam in various proportions have also been employed in particular cases of working. The use of the counter-pressure working has the important advantage of rendering the great weight of the engine available as brake power ; and as the amount of retarding power obtained from the counter-pressure steam against the pistons when running reversed is less than the propelling power of the steam in ordinary working, the engine wheels are not skidded upon the rails ; but a steady retarding force is continuously applied to them within the limit of their adhesion. The wear of rails and tyres that is caused by the friction of the train wheels when skidded by the ordinary brakes, and the consequent injury to the wheels by wearing flat places in their circumference, are avoided to the extent that the counter-pressure steam is used as a brake on the engine ; and the practical working of the counter-pressure plan has been found so satisfactory, that its use has even been carried so far in many cases as to supersede the employment of the train brakes, not only in descending inclines, but also in stopping and shunting at stations. In shunting, the steam regulator is left constantly open, and the motion of the engine is controlled entirely by the reversing handle. The employment of the counter-pressure working has now been extensively adopted in France, Spain, and other countries, as many as 1,400 locomotives being regularly worked on this plan on the Paris and Lyons Railway alone, both in descending inclines and in stopping and shunting at stations ; and in all cases its adoption has been attended with complete success.

The Fairlie Engine and Steam Carriage Company, in a communication to the "Engineer," write :

"We have very carefully investigated every description of brake that has yet been proposed, and at last decided that the Le Chatelier brake was superior to all others, because of its great simplicity and its wonderful efficacy. Before definitely deciding, however, we spent some time with M. Le Chatelier on some of the principal lines in France, inspecting and testing his system with long heavy trains on steep inclines and heavy shunting work at stations. In no case was there ever the least difficulty, the driver regulating or stopping his train by simply opening or shutting a small tap placed ready to his hand. In one case with a train of 326 tons, including the engine, we ran from Commentry to Moulins on the Paris and Orleans Railway, distance 104 miles. From Commentry to Villafranca, there is an average descending gradient of 1 in 60 for 10 miles, down which we ran without the assistance of any brake whatever, the little tap on the boiler doing all the work. We varied the speed at pleasure—now 15 miles an hour, now 10, now 12 ; we no sooner desired an increase or reduction of speed than it was accomplished, so beautifully did the apparatus work, and all done by simply altering the position of the steam and water taps. The cost of supplying the apparatus, and fitting the same to any ordinary engine will not exceed £20. The whole arrangement is simple, although the steam and water taps require to be very carefully and nicely regulated, also the nozzles of the jets in the exhaust pipes require to be very carefully directed.

"We have just completed a series of experiments made this day with the 'Progress,' with the counter-pressure brake, and the result has proved most satisfactory. With a train between Hendon and Kentish Town, the gross load of which was 650 tons, we stopped on a gradient (the rate of grade at this moment we do not know), in 300 yards, the speed being fully twenty miles an hour at the commencement of applying the back pressure."

ROTARY STEAM-ENGINES AND HOT-AIR-ENGINES.

Translated from "Der Practische Maschinen Constructeur."

That kind of steam-engines in which the expansive power of steam acts directly upon rotating parts (pistons) is illustrated by a great number of plans and models, but by very few machines in actual operation. And these will have but a brief day for their limited sphere of use, as their performance is not for a moment to be compared with that of machines with reciprocal or oscillating piston motion. Why are all existing constructions of rotary steam-engines useless, and why do men continually labor to invent new machines of a kind proven to be the least effective of all? Those machines in which the principal parts are free from all alternating motion are in such a primitive condition, and so little suited to the properties of steam, that they may well be called playthings. A single notable exception is the machine of the Patent-Disc-Engine Company. And this has the fault of all rotary steam-engines—great friction and little steadiness. The second class of machines, in which, besides rotary pieces, there are also driving or driven pieces which have reciprocating motion, are only bad modifications of the present cylinder machine, in which rectilinear movement is in the simplest possible way converted into rotary. In this sort of engines we meet with ridiculous notions, and we find it hard to understand how practical men can run so wild in pursuit of novelties. It must be granted that very ingenious constructions are somtimes devised. But in all there is the same fault—very great friction or lack of stability, or both. Every practical man of moderate experience in this direction knows how difficult it is to steer clear of these defects.

A power of little intensity, but great quantity, can be increased in intensity if it be taken up and delivered or translated at a proper velocity. A body will acquire a much greater mean velocity by revolution than by a rectilinear oscillating motion. It will take up and impart a much greater quantity of power working uniformly, and will do so without requiring more room. A turbine requires but a fraction of the room required by an ordinary water wheel using the same quantity and the same head.

There would be a like difference between the space occupied by a rotary and a cylinder engine, if we could but assume that the useful work of the two is equal.

This fact, the dispensing with heavy regulators, and the illusory assumption of a greater useful effect, have been the motives in the construction of rotary engines. As long as inventors attend to these points only, and their effort is directed to change of the corresponding mechanism, so long will it be hard for rotary machines to claim attention as useful working engines.

We shall find other helps to the solution of this problem by a critical consideration, not of the mechanism, but of the peculiar principle of these engines, and the properties of their corresponding motive powers.

(1.) A permanent gas under a pressure of 0.5 atmospheric, friction taken into account, flows through an opening of 10 centimetres with a velocity of about 250 metres a second. If the gas, instead of flowing freely, drives a piston which moves with only 0.1 of the velocity of the gas, it would move 25 metres in a second. How long would machines with some parts affected by alternating motion hold together? Such velocity, and greater, can be given without damage to revolving parts only.

(2.) Suppose the pressure of the gas to be 0.5 atm., equal to 0.515 kilog. per. sq. metre, and the velocity of the piston to be 25 metres; a piston of 10 centimetres area would give a work of 129 sec.-kil. or 1.7 H. P. If a machine could be made giving 0.1 effective work, then the piston that is to do the work of 1.7 H. P. must have an area of 100 sq. centim., while the engine itself would need but small dimensions.

(3.) To give a permanent gas a tension of 0.5 atm., for a constant volume, only 150° C. is neccessary. If 200° C. is taken to compensate for loss of heat, still this is low enough to prevent impairing the efficacy of unguents.

(4.) The more rapidly a piston is moved by the pressure of a gas, the less closely does it need to fit the side of the cylinder, since the friction of the gas in the narrow space between, does not allow a great velocity of transmission of gas; in fact, at the normal velocity of the piston it is entirely prevented, especially when the tension of

the gas is weak. Unnecessary friction, and the consequent loss of work and destruction of bearing surfaces, are thus prevented.

(5.) The advantages mentioned in (3) and (4) disappear when gases of high tension are used. Closer contact is necessary, and friction therefore increases; oiling becomes impossible, as unguents cannot resist the great heat.

Gases under high tension can give out their driving power with advantage, only when they work expansively, which makes a complex apparatus neccessary; and this, combined with a complex mode of operation of gas, puts difficulties in the way of rapid motion of a machine, while on the other hand friction gives more difficulties to slow motion.

(6.) The conditions are still more favorable when, instead of a permanent gas, steam is applied as a motive power. For its economic use, expansion and condensation are neccessary. In the generation of steam, its full operation, its expansion and its condensation, are involved processes on the one hand simultaneous, on the other sharply distinct, which may not follow close one upon the other if they are to produce effective work. The speed of steam-engines must not be too great for useful work. Herein lies the chief advantage of rotary machines, because of the rapidity of motion that can be turned to useful effect. Slow motion brings with it the defects already mentioned, and adds to cylinder machines not one advantage which is not cancelled by some equal disadvantage. Experience has shown this, and theory has proved it.

(7.) Hot-air engines in their present form must be of great dimensions, and out of proportion, in order to produce work of any account. Besides, an extraordinary heat is required for the neccessary tension. Under these circumstances there remains the unsolved problem—to furnish a simple and effective contact, to oil the working parts well, and to prevent heated parts from quick destruction. The defects will remain so long as we make hot air work in cylinder engines, which cannot convert weak tension into quick motion.

What has been said sums up as follows: The peculiarity of rotary machines is, not that they drive by means of steam or of intensely heated permanent gas of high tension, but that they drive by means of a permanent gas to which a moderate tension is given by heating to about 200° C. On the other hand, steam, not heated air, is suited to the cylinder engine. The mechanism which takes up the force and converts it for our use must be fitted to the force; so steam and cylinder engines consort, and hot air with rotary engines. The rotary engine makes the conversion of heated air into motive power possible, while the application of heated air as a motive power makes a corresponding construction of a rotary machine possible. If the mutual harmony of machine and of power is recognized, the joining of both in a harmonic whole will not be wanting.

The Age of Iron.—In these islands alone 500 blast-furnaces are blazing; reducing, by their intense heat, nearly 12,000,000 tons of iron ore to 4,800,000 tons of metallic iron, which, at its place of production, has a value of about £11,000,000 sterling. Those blast furnaces consume more than 14,000,000 tons of coal; and to convert the pig-iron obtained into bars, rails, and the like, a like quantity of coal is required. The great iron industry is not confined to the British Isles alone. In France it is no less active, and it boasts of iron-works which rival those of Dowlais, of Barrow, or of Middlesbrough. The works of Messrs. Schneider & Co., at Le Creusot, the largest in France, have 50 acres under cover. Here are 15 blast-furnaces, with 27 steam-engines blowing air for them, and forging iron besides. At the mines and works over 3,500 men are employed. Belgium, Prussia, Austria, and Sweden are active in this great race; and America is striving, with earnest and honorable zeal, to overtake Europe in the production of iron from her native ore, with her own coal.

A writer in the "Times" proposes, as amongst the best means for preventing railway accidents, that station platforms should be raised to the level of carriage floors, and brought within 3 in. of the carriage sides; that a net should be fastened over the spaces between the carriages, and that engines should be fitted with an apparatus in front in the shape of the mould-board of a plough, and adapted to throw all obstacles out of the way of the train.

LONG AND SHORT SPAN RAILWAY BRIDGES.

By JOHN A. ROEBLING.

A brief reference to the contents of the work referred to above will be of interest to our engineering readers.

The theory of the parabolic truss is set forth with great clearness, and without the use of troublesome formulæ, and is followed by details of arrangement and calculations of strains for spans of 500 ft.

In illustration of the use of the parabolic truss, in combination with a system of stays, two cases for spans of large magnitude are given. One of a central span of 500 ft. and two side spans of 300 ft. The other, of a central span of 600 ft., and side spans of 420, besides minor side spans of 150 ft. Some of the designs were prepared for special localities, but can be adapted to every possible range of profile and situation, and for every length of span desired.

For spans above 600 ft., the combination of the upright and inverted arch is replaced by the pure suspension principle, stiffened by a truss, which is provided with sliding joints at the ends of the stays, to provide for expansion and contraction, both towers being fixed in this case. The illustration presents a main span of 800 ft., and two side spans of 548 ft.

Engravings on a large scale, and of the highest excellence, exhibit the structure as a whole in a most impressive manner; to which are added the details, on a larger scale, of combination and dimensions, and tabular statements, with weights and estimate of cost of construction.

There are also given the means and manner of erection of such large spans, without obstructing the iron by scaffolding.

A large amount of engineering information is thus given in a most complete and practical manner.

Three other designs of bridges of large span show the different modifications of the parabolic truss principle. The tension of the cable, instead of being taken up by an anchorage, resists the thrust of the arch directly, by an anchor-plate. The arch may be cut off at any point of its curve, to suit the convenience of site in determining the length of land spans.

The structures throughout are of iron, including wrought-iron towers on the stone piers. One tower is fixed on its pier; the other tower, with the rest of the structure, being free to go and come.

The designs for the short-span bridges are accompanied by reference to the circumstances and considerations which determine where the parabolic system can, and where it cannot, be used with economy.

It will be noticed that the unit of load adopted is considerably above the unit ordinarily adopted, and that fact must be borne in mind when making comparison with the known cost of other structures.

The six tables of weight and cost of trussed girders for spans of 200 to 400 ft., with and without wire cables of iron or steel, include the statement of strains and sectional areas and units of tension and compression, and are thus of the highest practical value.

[We insert the introduction to Mr. Roebling's work, that our readers may have the privilege of reading the last published words of the great engineer. —Ed.]

INTRODUCTION.

No continent can boast of a more magnificent system of water-courses than ours, and on no other continent will there be a greater development of internal commerce, by land as well as by water. The construction of long-span railway bridges over our large navigable rivers, such as will not materially interfere with their free and easy navigation, becomes therefore a question of national importance.

Who can estimate the tonnage of the future (say one or two hundred years hence), which will be floated upon our navigable water-courses. Considering now that this immense tonnage will have to be moved at low rates, and that this can only be done on the *barge* system, and that large tows, measuring from one to two hundred feet across, require ample water-way in passing a bridge, and that they cannot, without great risk, be exposed to oblique currents, produced by the close proximity of piers, the necessity of large openings in bridges becomes self-evident.

Another important consideration in favor of long spans is presented by the

fact that foundations in the large rivers of the West, in order to be safe, must be sunk to the rock, else their security will be endangered by the deep scour caused by floods. This depth of scour may be caused by an ice-flood, when narrow spans are apt to produce ice-gorges, and thus force the current to undermine shallow foundations. But deep foundations are expensive, because the stability of piers of 150 to 250 ft. high requires a broad base and a corresponding mass; hence the economy of larger spans, by decreasing the number of piers, is apparent at a glance.

Economy in construction will be the test of the future. Sooner or later those plans and systems alone will survive in practice which are the most economical; those alone will be adopted by the competent engineer which will afford the greatest amount of strength for the least amount of cost.

Ever since the question of suspension railway bridges has been discussed, the opponents of this system have never objected to it on the score of economy; on the contrary, they are always willing to yield this point. Their apparently insurmountable objection is the inherent flexibility of such structures—great enough in imagination to endanger the safety of passing trains. The utter groundlessness of this objection having been demonstrated by the complete success of the Niagara bridge, the low speed of trains maintained on this work is now made another potent argument.

To meet this I will draw the attention of those who have not made up their minds on the subject, but who honestly seek further information, to the fact that all the large wooden railway spans, whose safety has never been doubted, are, in proportion to the span, more flexible than is the Niagara bridge. All iron bridges are flexible, because of the elasticity of the material composing them. But wooden structures are more so. A wooden truss of 200 ft. span, after a few years' use, will readily yield from 3 to 4 in. in the centre under the passage of a heavy train. The deflection of the Niagara bridge when taxed with a fully loaded freight train, from end to end, is 10 inches, and this is principally owing to the straightening of the anchor cables. Suppose an ordinary wooden truss was lengthened out to 800 ft., and suspended by cables, its flexibility would be about the same as that of the Niagara bridge, and less in proportion than the 200 ft. span *without* cables. Now has any engineer objected to our wooden railway bridges on the score of flexibility? The man who did would be laughed at.

I here repeat what I have said on former occasions, that the principle of suspension will of necessity become the main feature in our future long-span railway bridge.

Theoretically considered, the principle of the arch, in an upright as well as in a suspended form, is the most economical. It will hold equally good in practice, if properly applied. To obtain the largest degree of economy, however, the two positions of the arch, the upright as well as the inverted or suspended, must be combined into one united system; and this system is now well known, and was equally well known in the last century, as the *Parabolic Beam*, or the *Parabolic Truss*, as I prefer to designate it. The principle of the Parabolic Truss forms the main feature of the plans herewith presented. It has been applied with a view to economy as well as stiffness.

As to novelty of invention I claim nothing. Most of the combinations may be, and no doubt are, novel; but they are only different illustrations of the same old and well-known principle.

To prevent and forestall the issue of trifling patents, such as would be a disgrace to the American profession of Civil Engineers, is one of the objects of this publication.

In the nature of things, no plan can be devised for large central railway spans, with lesser spans adjoining, which offers equal strength and stiffness at the same low cost as does the Parabolic Truss as here designed. For large single spans, and for openings exceeding 700 ft., the pure suspension plan with a judicious system of stays and trusses, as is found in the Niagara and Cincinnati bridges, will be most economical, and sufficiently stiff for all railway traffic.

These statements may appear at the first glance rather positive, but by and by they will stand out no longer as individual opinions, but they will establish themselves as *great engineering facts*, and moreover an *American necessity*, because we have to deal with large navigable rivers;

and navigation will not be suffered to be destroyed by incompetent engineering. Ignoring minor attempts, the first successful endeavor to apply the Parabolic Truss on a large scale is due to the late Mr. Brunel; who, in the Saltash bridge, has left a remarkable proof of his practical genius.

Without copying Brunel's model, the same system has found very extensive and successful application on the continent of Europe, and is more particularly known in Germany as Pauli's system. The largest and most noted work in that country, built upon this plan, is the railway bridge over the Rhine at Mayence, with four river openings of 101.29 metres each in the clear, equal to 322 ft. 5 in., English measure.

Within the last year a distinguished Austrian engineer, a man of great practical experience in iron railway bridges, Carl von Ruppert, has published his magnificent plan for a great railway bridge over the Bosphorus, near Constantinople, with a central opening of 650 ft. (Austrian measure) and two side spans of 513 ft. in the clear.

Without entering upon the details and general merits of this justly celebrated design, it must be acknowledged that it is a most beautiful application of the principle in question. But on the score of economy, safety, and cost, this design is much inferior to a pure suspension bridge, which, without any costly piers and foundations in a deep sea channel, may be thrown across this famous strait, from shore to shore, in a single span of 1600 to 1700 ft.

In this number the plans and estimates are given of a bridge spanning a centre opening of 500 ft. in the clear, with two side openings of 300 feet each; also the plans of the St. Louis bridge. In order to enable the practical engineer to make all those calculations which are really necessary for determining the principal strains and forces, I have also introduced a few theoretical considerations. Elaborate theories are out of place in a work designed for practical men alone; they may be found in every standard work on Statics and Mechanics.

As time and health shall permit, other plans will be prepared, to follow this number, designed for long spans as well as short.

JOHN A. ROEBLING.

TRENTON, N. J., *Sept.* 1, 1868.

THE LONDON WATER SUPPLY.

From "Engineering."

It is more than two years and a half since the committee appointed to examine into the condition of the Metropolitan Water Supply, commenced their labors but recently terminated, these being recorded in a report, the conclusions of which we have already published. The probable future metropolitan water requirements, and whether the source whence its present supply is derived will be sufficient and reliable in all ways for the coming generations, or whether we should begin to look elsewhere than to the Thames Valley for our main supply, were the questions which the committee had to set themselves earnestly to consider; and, judging from the voluminous evidence they have received, from the personal examinations they have made, and from the care with which they have weighed evidence and studied the physical peculiarities of the basins of the Thames and of the Lea, we are bound to assume that their recommendations are correct, and that the Thames and the Lea, which have hitherto supplied London with water, will never fail, either in quantity or quality, in serving the metropolitan demand, even though it should grow and extend itself in a proportion which the increase of the decades of the past does not warrant in assuming for the future.

Two hundred millions of gallons of water a day is estimated as the future necessary supply for a population swelled to 5,000,000; nearly 200,000 tons of water distributed over an area of 224 square miles, through mains and branches and service pipes to meet individual demands, or public wants; forty gallons being apportioned to each unit of the 5,000,000 every day. Times are changed, and necessities have increased since the city ran with sparkling streams from the high lands

on the north of London, and carried a plentiful supply, which could be had for fetching; or since the local springs were collected and led by conduits through the city. The streams have long since disappeared, changed into sewers, arched over out of sight, and nothing but the names are left of the conduits to mark the course along which they ran. But these supplies were too limited even for London of the sixteenth century; and three hundred years ago came Peter Morrys, the Dutch engineer, who utilized the constant flood pouring through the narrow archways between the piled-up starlings of old London Bridge, to drive pumps that raised water and supplied, by wooden mains and by open gullies, the neighboring streets for two centuries after his time.

In 1609, Hugh Myddelton commenced the formation of the New River, bringing the springs from the chalk at Chadwell and Amwell, near Ware, to within a few miles of London. Funds failing him then, the work was completed by the help of a royal grant, in doing which, by the way, royalty looked well after its own interests, and thus, seven years after the act had been obtained, the northern parts of London were supplied by a plentiful flow, secured by gravitation. Soon after its completion the waters from the chalk springs, which originally formed the only source, were supplemented by an inlet from the Lea.

These two works, together with the natural streams and open conduits, formed the water supply to London till the end of the seventeenth century. But in 1691 a company was formed under the title of the York Buildings Water Works Company, to supply the city of Westminster, the water being pumped from the Thames near Charing-cross. These works existed so late as 1829. In 1723 came the Chelsea Water Works to supply a district of Westminster and the growing neighborhood westward. At first the pumps were erected at Millbank, and afterwards removed to a site near to the present Victoria railway bridge. Meanwhile, the narrow arches of old London Bridge were filled with water wheels that clumsily raised water for the city as well as for Southwark. In 1785 the Lambeth Works had started and pumped their supply from the Thames opposite Charing-cross, and the Borough had established pumps not far from Blackfriars Bridge. With the beginning of the century most of the companies which now supply the metropolis came into existence. The West Middlesex Water Company at Hammersmith in 1806, to supply the western suburbs; the Grand Junction, five years later, who, starting to draw their water from the Colne and the Brent, aided by surface drainage, soon had to resort to the Thames for a purer and more constant supply, and in 1820 their sluices drew from the river near to Chelsea Hospital. Eastward the East London Water Works, dependent for their supply upon the river Lea, superseded two small establishments at Shadwell and Ham; and shortly after their act had been obtained, in 1806, works were erected near Bow. In the southern districts the Vauxhall Water Works were started in 1805, taking their supply from the Effra, then an open confluent of the Thames, and but recently converted into a covered sewer. The various companies thus established, before long, trading on their monopolies, began to levy rates, which resulted in a continued public dissatisfaction, and in 1821 a commission was appointed to examine into the subject. Their report, recommending considerable reform, was never officially acted upon, but it had the effect of inducing the water companies to remove the chief cause of complaint. The quality of the water supplied was the next subject that claimed general attention. The various companies drawing their supplies from the river, polluted by the sewage discharged into it, distributed it direct throughout their respective districts without any intermediate process of purifying. In 1828 a commission was again appointed to inquire into the quality of the supply. The examinations conducted by this commission showed that the general outcry was a just one, and that the supply, especially from the works below Westminster Bridge, was totally unfitted for general use. Filtering beds, settling reservoirs, and removals to new sites followed the publication of this report. The Chelsea Company, in 1829, laid down the first large filter of one acre in extent; the West Middlesex and the Grand Junction removed their source from Chelsea to Brentford; the East London went higher up the Lea, and the Southwark and Vauxhall, combining, established new works at Battersea.

A report by Mr. Telford was made in 1834, in which it was recommended that entirely new sources of supply should be sought, and in which Mr. Telford suggested the Verulam on the northern, and the Wandle on the southern, side of the metroplis; but this report, although discussed in both Houses, remained entirely unacted upon.

The partial improvements introduced by the various companies after 1828 tided matters over for several years, but the development of sanitary engineering resulted in so largely increased a discharge of impurities into the river, that an efficient filtration became impossible, and it was obvious that the time had arrived when some of the most important companies must change their source of supply, or abandon their works altogether.

The Lambeth Company, situated in a most unfavorable position, were the first to take active steps towards the unavoidable change. In 1848 they obtained a new act, and three years later water drawn from Kingston, far beyond the influence of the tide, was delivered through the mains of these extensive districts.

In 1850 the General Board of Health, who had by that time developed into a most useful and powerful body, issued a report, the minutes of which pointed out strongly the evils existing from the system of deriving a large supply from the tideway of the Thames, and, indeed they went so far as to assert that the river should only be utilized temporarily for obtaining water beyond the influence of metropolitan drainage, until a more favorable locality could be decided upon, and centralised works erected; and they pointed out the large tract formed by the Bagshot sands, and the lower greensands in Surrey, as suitable for the purpose. This proposition might possibly have been acted upon had not a company at that time been projected for the purpose of supplying London with spring water from the chalk at Watford. The scheme had been so favorably noticed by Robert Stepenson, in a report made ten years before, that it was thought advisable for a commisson to investigate chemically the quality of the water obtainable above the tidal influence. The result of their inquiry showed that such water could be thoroughly relied upon for public use, and, condemning the Board of Health proposition relative to turning to the Bagshot sand as a source of supply, they recommended the consideration of the Watford scheme, assuming that the hardness of the water derived from chalk could be destroyed by Dr. Clark's process of softening.

The termination of all these investigations was a decision that legislation on the subject was necessary, and in 1851 a bill was introduced into Parliment for the amalgamation and centralization of all the water companies, and the obtaining of all water from one common source. Opposition overcame this measure, but it resulted in an act being passed the following year, by which stringent and important obligations were imposed upon the various companies, who were left otherwise free to pursue their business independently. The most important clauses of this bill rendered it compulsory that no water should be drawn from the river below Teddington; that all the city storage reservoirs should be covered; that all water, unless pumped from wells should be effectually filtered.

After the passing of this bill, the water companies proceeded to make alterations in compliance with its clauses, which involved an expenditure of £2,500,000, and with the result, ascertained in 1856, of considerably reducing the amount of organic matter.

Of the eight companies now supplying the metropolis, five are situated on the north side of the Thames, and three on the southern side. In the long series of articles published in the second volume of "Engineering," under the title of "The Waterworks of London," the whole of these works were fully described in detail.

The number of gallons given in the last column of the following table, as the amount of daily supply, gives only the average, and not the maximum quantity, which in the summer months is augmented to 108,313,000 gallons, showing an excess of 10 per cent. of consumption in the summer over the winter months.

Collectively, the various companies possess forty-four subsiding reservoirs, occupying 260¼ acres; the filtering beds number forty-eight, with an area of 51⅛ acres; they own twenty-eight storage reservoirs, having a capacity of 112,087,000 gallons; and ninety-six pumping engines, of 10,660-horse power in all.

Table giving the General Statistics of the various Establishments in 1867.

	CAPITAL.	APPROXIMATE AREA OF DISTRICT SUPPLIED.	NUMBER OF HOUSES SUPPLIED, 1867.	ESTIMATED NUMBER OF PEOPLE SUPPLIED, 1867.	AVERAGE DAILY SUPPLY, 1867.	
		Square Miles.			Gallons.	
From the Thames:						
Chelsea Company	£785,600	6.5	26,875	170,000	8,087,258	
West Middlesex	798,571	10.0	36,881	275,000	8,816,486	
Grand Junction	850,000	24.0	27,190	245,000	9,533,432	
Southwark and Vauxhall	1,100,440	30.0	71,558	465,000	13,629,758	
Lambeth	736,245	25.0	38,320	230,000	8,975,530	
						49,042,467
From the Lea:						
New River Company	2,609,418	19.0	113,462	800,000	23,790,667	
East London Company	1,400,000	50.0	92,652	675,000	19,298,241	
						43,088,908
From chalk well, Kent:						
Kent Company	489,240	60.0	34,504	240,000	6,468,873	6,468,837
Total	8,769,514	224.5	441,442	3,100,000	98,600,248	98,600,248

By their present acts and agreements, the companies are empowered to draw 110,000,000 gallons daily from the Thames—the Chelsea, West Middlesex, Grand Junction, Southwark and Vauxhall, and Lambeth Companies, each taking 20,000,000 gallons, and the East London Company (under a recent act), a quantity equal to 10,000,000 gallons. From the Lea, the average quantities actually taken, are : 18,000,000 gallons by the New River Company, their total delivery being 23,750,000 gallons; and the East London take 19,250,000 gallons from the Lea, at a point lower down the river. Besides these quantities, the chalk wells of the Kent Company yield 7,000,000 gallons daily.

The Commission of 1865, appointed to inquire into the best means of preventing the pollution of rivers, reported that the accumulating sewage discharged into the Thames by all the towns and villages along its course, tended seriously to impurify the river, and that efficient means should be taken to compel the diversion of the discharge, and the utilization of the sewage upon the land. The report resulted in the act passed the following year, which legislated for the towns along the Thames Valley, and fixed a limited time for the completion of the dictated improvements, a limit which, by the way, has been exceeded hitherto with impunity. This commission, and also the committee appointed in 1867 to inquire into the condition of the river Lea, were of opinion that with the recommended alterations, both rivers were efficient sources of supply, and that there was nothing to justify incurring a vast expenditure in the formation of new works.

The lengthened discussion which had taken place, and the epidemic which visited London in 1866 (the cause of which, it was alleged, might be traced to the water supply), brought forward many schemes for obtaining a pure supply from a foreign source ; of these the principal were Mr. Bateman's project for utilizing the sources of the Severn ; Messrs. Heman and Hassard's plan, looking to the Cumberland and Westmoreland lakes ; Mr. Fulton's project for drawing water from the Wye ; and Mr. Remington's plan of obtaining it from the Derbyshire hills.

All these different systems, which have been fully described in previous volumes of "Engineering," were carefully examined into by the recent committee, who concluded that, setting aside all other considerations, there was not sufficient information upon the reliability of the rainfall. "It is evident," they say, "that a long series of observations is necessary to be made before any authoritative opinion can be expressed, not only as what may be the true average rainfall, but what may be the mean of the three driest years, and at what intervals they occur. In the case of a large city like London, where such a source of supply is proposed, an exact determination seems to us imperative. Of

course it will be understood that not only should the observations extend over a long series of years, but also that they should be made in many places so as to get at the average rainfall of the district, which has well been shown to have very different values in immediately adjacent places, as it varied in the same year in fourteen areas in the lake district, from 45 to 100 in. The system of collecting grounds utilizes, no doubt, the rainfall to the greatest extent. But the great disadvantage is, that the springs to fall back upon in time of drought are insignificant in comparison with the great quantities stored in permeable strata. The very circumstance of a large immediate delivery of the rainfall, precludes the possibility of that subterranean storage of a large portion of it, which forms so valuable a resource during severe and long-continued droughts."

These objections are substantiated by the experience gained from towns furnished with gravitation—supplies which have in nearly all cases failed in seasons of drought, when the requirements were the most urgent. Liverpool, Manchester, Newcastle, Rochdale, Preston, Bradford, Halifax, and other towns supplied by this system, have all suffered from a temporary deficiency, or even an absence of water, which involved the hasty extemporizing of other means to meet the unexpected demands, or the erection of permanent pumping works to supplement the insufficient ones already existing.

THE HEATON STEEL PROCESS.

MONSIEUR GRUNER'S REPORT.

From "The Engineer."

We lay before our readers an English translation of the long-expected memoir on the Heaton steel process, by Monsieur L. Gruner, the eminent Professor of Metallurgy of L'Ecole des Mines, Paris.

THE HEATON PROCESS.

The purification of pig-iron by the Heaton process is based on the reaction of nitrate of soda, which is at once basic and oxidizing. The nitric acid oxidizes the silicon, the phosphorus, and the sulphur; the soda seizes on the acids so formed, and withdraws them from the reducing action of the iron. These reactions are known, but the difficulty in operating on large masses is to obtain a sufficiently intimate contact between the molten metal and the nitrate to produce an efficient purification, without, however, causing an action so energetic as to result in violent explosions. Mr. Heaton adopted several contrivances in succession, which I need not review. It will be sufficient to describe his latest improvement, which has the great merit of being both simple and cheap.

This apparatus consists of a cylindrical vessel with a movable bottom, a kind of cupola without tuyeres, into which is run the molten metal to be purified. In England it is called a Bessemer's converter. The movable bottom is a cylindrical cauldron of sheet-iron, provided with two trunnions, which allow of its being held by a forked lever mounted on a wheel carriage. By this means it is removed and replaced after each operation. The interior of the cauldron is lined with bricks or refractory clay, worked into the shape of a hemispherical basin.

The converter and its movable bottom are provided with flanges which are held together by clamps and wedges for each operation. The converter itself is lined with fire-bricks, and provided with a sheet-iron chimney like a cupola; on the top of the chimney is a sheet-iron cap, intended to stop the projection of incandescent slag and metal, which might take place in the event of a too violent deflagration of the nitrate. The molten pig is poured into the converter through a lateral aperture, a sort of box funnel, which can be closed at will by a wrought-iron lid, or simply by a brick. The dimensions vary with the weight of metal to be treated at each operation. There are four converters at Langley Mill, two large and two small ones, the latter are used for charges of about 15 cwt., the former ones for more than double that quantity. But that is not the necessary limit of their capacity; like the Bessemer converters,

they can be made of any size, and, as in the Bessemer process, on account of the heat absorbed by the lining of the converter, the operation, within certain limits, is the more uniform as the volume of metal treated is increased. Still the process is successful even where the charge treated does not exceed 2 cwt. The interior diameter of the 15 cwt. converter is 29 in., and the depth of the bottom is about 12 in. The distance from the spout of the box-funnel, into which the molten metal is run, to the bottom of the nitrate chamber, is 4 ft. 3 in., and from the same funnel to the top of the vessel 36 in. Above this is a simple chimney of sheet iron, slightly conical, the height of course depending upon the height of the roof of the works, through which it has to be carried. The large converters for 3 tons have an interior diameter of 39 in., and the depth from the funnel to the bottom about 78 in. The molten metal to be purified may be taken direct from the blast furnace, and in fact it ought always to be so, unless, indeed, the modifications I shall presently recommend be adopted. Treatment direct from the blast furnace was the method pursued at the Stanton Works near Trent, in the Erewash Valley, while at Langley Mill itself, there being no blast furnace, the pig is run down in a common cupola. But this arrangement is simply experimental, and not to be taken as a model for imitation in the erection of new works. The essential feature of Mr. Heaton's invention lies in the arrangement of the nitrate chamber. To insure the gradual decomposition of the salt by the molten metal, the nitrate must be tightly packed into its chamber, and further protected by a perforated cover. If the stream of molten metal fell directly on the nitrate, it would at once penetrate and force its way to the bottom of the mass. The action would be most violent and instantaneous, and the alkaline salt would soon float without efficiently permeating and reacting on the molecules of metal to be purified. To avoid this, the above-mentioned perforated cover is placed over the nitrate when it has been packed into the movable bottom; it is a thin plate of cast or sheet iron perforated with a great number of holes about $\frac{1}{2}$ in. in diameter. Mr. Heaton habitually uses a cast-iron plate of about $\frac{3}{4}$ in. in thickness; but a piece of thin sheet-iron seems to me better, and answers better in the little experimental 2 cwt. converter which Mr. Sharpe has lately erected at Villette near Paris. To prevent the displacement of the plate by the molten metal, it is held down by wedges of iron or brick. These wedges are laid between the plate and two flat iron bars laid across it, and nipped by the projecting flanges of the converter and the nitrate chamber; moreover, to prevent any leakage, the joint of the flanges between the bottom and the converter is futed by slightly moistened moulding sand. Then the clamps and the wedges bind them together and make all sure. When the converter has been thus prepared, all is ready for the reception of the molten metal to be treated. Having been present at some twelve conversions, I will first of all relate the general plan of operations. I will then give an account of the results obtained from the Moselle pig irons. I will proceed to give my analyses, which will show what degree of purification can be effected by this process. (I should say here that I visited Langley Mill in December, 1868, accompanied by Mr. Sharpe, an English engineer, acting for Mr. Heaton in France, Baron G. d'Adelsward, and M. Thiéblemont, engineer of the house of de Wendel et Cie, the object of our visit being to ascertain the effect of the process on the pig irons of the Moselle district.) The principal reagent used by Mr. Heaton is Peruvian nitrate of soda; but he habitually mixes with it a certain proportion of quartzose sand, some times lime, peroxide of manganese, fluor spar, etc. We shall see that quartzose sand and lime are more generally detrimental than otherwise, but peroxide of manganese, carbonate of soda, and sea salt may advantageously be added to the nitrate. Indeed, Mr. Heaton himself has abandoned the use of lime, and now generally uses from 6 to 12 per cent. of nitrate with 1 to $1\frac{1}{2}$ per cent. of sand.

These two ingredients are thoroughly intermixed and then closely packed into the nitrate chamber, which has been previously dried.

The nitrate used is the ordinary nitrate of commerce; it contains from 5 per cent. to 6 per cent. of water, and 3 per cent. to 4 per cent. of foreign substances. A sample which I brought back from Langley Mill was analyzed at the School of Mines with these results: Water, 5.88;

sand, 0.28; sulphate of lime, 0.22; chloride of sodium, 2.73; pure nitrate of soda, 90.89. It was tested for phosphoric acid, but it only contained the merest traces of it. According to this, 100 of crude nitrate contains 33.27 of soda, or rather 34.7, if we reckon in that which is found in the condition of chloride of sodium.

The molten pig to be converted is tapped out of the blast furnace or the cupola into a ladle of sufficient capacity to contain the weight of metal to be converted. By means of a crane or a traveller the ladle is brought up to the box-funnel of the converter, and the molten metal is poured into it. If the molten metal be hot and fluid the reaction begins at once; the perforated plate lets the metal pass, the nitrate is gradually decomposed, the oxidizing gases, mingled with streams of soda, rise through the bath of pig and cause an ebullition more or less violent, which sometimes makes the whole converter tremble, and is accompanied invariably by a roar similar to that which is heard in a small Bessemer converter.

Throughout the conversion a vast volume of dense vapors issues from the top of the chimney; at first they are white, then yellow, orange, or gray, according to the kind of pig under conversion, and at last almost black; then, if the reaction be at all violent, the vapors take fire and burn for some seconds with a most intense yellow flame. When the reaction is less violent the gases only burn inside, then jets of flame sometimes force their way through the joints of the lid of the box-funnel. When the reaction is still more violent, or when the metal is not sufficiently fluid, there occasionally takes place, as in the Bessemer converter, some projection of incandescent slag and metal with showers of sparks; but there is never anything like an explosion. In some conversions the reaction at first seems very slow and feeble—there seems actually no commotion; then, all on a sudden, a violent action takes place with disfiguration and violent projections. This spasmodic action is doubtless caused by the sudden breaking up of the perforated plate and the consequent too violent irruption of the molten metal. This accident happens, in fact, when the plate is badly secured or cast of too brittle a material; on this account a plate of thin sheet-iron is decidedly preferable to a cast-iron plate. (In the small converter at Villette, which only holds 2 cwt., the metal is apt to choke the perforations of the plate if thin sheet-iron be not used.)

The conversion seldom takes more than from two and a-half minutes to five minutes, but occasionally, when the molten metal is not at a high temperature and cannot at once pass through the perforated plate, it lasts eight or ten minutes. The maximum duration of the vivid flame at the top of the chimney is one or two minutes. As soon as it has disappeared the vapors become lighter colored, and pass rapidly from black to light gray, and then to white. One can then open the lid of the funnel and, without any risk, observe the gentle ebullition of the metal at the bottom. It emits jets of yellow flame, and we can ascertain by an iron crow-bar the degree of fluidity and temperature of the refined metal. These both vary with the chemical composition of the pig treated. We shall see that silicious pigs give a very high temperature in conversion, as is the case in the Bessemer converter. When, however, charges of upwards of 18 cwt. are converted, the refined metal seems always fluid enough to be run into ingots or pig moulds, if the converter bottom were provided with a tap hole. This is not done at Langley Mill, and really there would be no great advantage in doing it, for the ingot would be entirely vesicular by reason of the gases which continue to escape in abundance as long as the metal is pasty; but the fact is none the less important to note, for it would allow of the purified metal being run out direct into another furnace to finish the refining.

At Langley Mill the metal is allowed to solidify in the nitrate chamber. When the ebullition has perceptibly diminished and the mass begins to solidify, the clamps are knocked off, the nitrate chamber is removed from the converter by means of the carriage lever above mentioned, and as soon as the metal has quite solidified the whole is upset and turned out on the plated floor of the works. The slag is separated from the solidified metal by means of hooked iron rods, and the metal itself is broken up by sledge hammers; even now we see numerous jets of yellow flame escaping from the incandescent mass. The refined metal, when entirely cooled, is more or less tough or

short, according to the proportion of the nitrate used and the original composition of the pig; the mass is cellular, like a great sponge. It is like the semi-refined metal which is taken out of the bottom of a "Comptois hearth" (four Comptois) at the commencement of the second period, to be submitted to the working (travail) properly so called. In the fresh fractures the metal is white, semi-crystalline, more or less granulated, according to the degree of decarburization, the vesicles are often iridescent, or even coated with a black film which is a little slaggy. The mass is certainly far from being homogeneous, as is proved by the look of the grain as well as by the analyses. Some portions are nearly iron or crude steel, what Germans call "wild stahl," which can be hammered; while others are more nearly allied to semi-refined pig or to finery metal more or less decarburized. This is what Mr. Heaton calls "crude steel."

The slags differ in composition, and correspond to the quality of pig treated. When the pigs contain a large percentage of silica, the slag runs into threads like glass. It shows a conchoidal fracture, and looks black in mass, but transparent and of a brilliant bottle-green color when broken off in thin chips. On the other hand, when there is but little silicon in the pig the slag breaks short, and solidifies quickly, as do all basic silicates. When cooled it is an opaque dull mass, of a brown-black or invisible green, having an uneven surface, showing a rough fracture, and being somewhat vesicular in structure. In either case the slag is full of globules of metal, and produces on the tongue the well known sensation caused by alkalies. The slags are attacked and partially dissolved by water.

The crude steel is treated in two different ways at Langley Mill. It is made either into wrought-iron or steel. In the one case some hundredweights are charged into a puddling furnace, the hearth of which has been raised with a view to its being worked simply as a balling furnace. To effect this object the hearth of the furnace is covered to a depth of some inches, with a mixture of sand and forge scales (*scoriæ de forge*) in equal proportions, well beaten down, and the sides are fettled with Cumberland red hematite; a charge of 6½ cwt., rapidly heated, is almost immediately welded into balls, which are then slingled into blooms under the tilt hammer. It is a kind of quick puddling, restricted to the time requisite for balling. The slags contained in the crude steel are liquefied and exude, and the finery process is completed simply by the welding heat. The actual process of heating lasts only half an hour; but as each bloom has to be taken back to the furnace for some minutes to undergo a species of balling before it is drawn out into merchant bars, the whole process in reality takes at least an hour. This balling enables them to dispense with piling, but when they want to produce superior iron they roll the shingled blooms at once into flat bars, rough, without any reheating. These are cut up, faggoted, piled, and rolled as usual. The total waste is 25 to 30 per cent. in this case; in the former, 20 to 25 per cent. The iron is tough and fibrous when it is piled, but hardly homogeneous. It is partly fibrous and partly crystalline when simply balled. Mr. Heaton calls this iron steel iron, but it is really ordinary malleable iron, which is in general hardly at all steely. In any event, to obtain malleable iron, of more or less tenacity, this process is too costly. Purification by the nitrate process is only feasible in point of cost, if the crude metal be converted either into homogeneous iron or cast-steel, and not into blooms; and this is the other method adopted at Langley Mill. The first product of the converter is, as I have said, crude steel, retaining still 1 to 2 per cent. of carbon. To convert it into cast-steel or homogeneous iron, the refining process must be completed, and the excess of carbon removed at the same time. To that end we must either use crucibles or a reverberatory furnace. Hitherto crucible melting only has been practised at Langley Mill, because it was necessary, in the first instance, to study the nature of the products. But this process is very costly, and Mr. Heaton always from the first intended to re-melt, on a large scale, in a reverberatory furnace. With this object, he had constructed a furnace with two combustion chambers, which was lighted on the occasion of our visit last December. The heat obtained was more than sufficient for the fusion of the metal, but the admission of an excess of air oxidized the metal and

converted it into slag. He would succeed better with Capt. Alexander's furnace (see my work on Steel, p. 74), and in any event with a Siemens furnace, such as is used by Mr. Martin at Sevreuil. At Langley Mill the re-melting has hitherto been done on the Sheffield plan, in crucible furnaces. Each furnace holds two crucibles, containing about 45 lbs. each. For convenience of charging, and to facilitate the selection of the different qualities of crude steel, which have to be mixed in the crucible according to the class of cast-steel which is required, the crude steel is hammered into flat cakes of about an inch in thickness, and these are broken up cold into small squares, just like the small pieces of cemented steel which are used for crucibles elsewhere. These cakes are prepared by heating the crude steel to a red heat in an ordinary reverberatory furnace, and then subjecting it to the action of the steam hammer.

As the crude steel retains an excess of carbon, and it is necessary to produce homogeneous iron or soft steel, pieces of wrought-iron are mixed with the cakes. For this purpose they use the crop ends of bars, or any other scrap iron of good quality that comes to hand. The cast-steel then is really obtained here by process of reaction, the admixture of a certain proportion of malleable iron with the purified pig. The refining can only be completed in the crucibles from which air is excluded by the ingredients contained in the metal itself, or added to the charge; and among these we must reckon the sodium, which is always present in small quantities in Heaton refined metal and metallic manganese, of which a small dose in the form of spiegeleisen is frequently charged into the crucibles. The reverberatory furnace has the additional advantage of the oxidizing action of air; so that, in reality, it possesses over the crucibles the double advantage of economy and of more completely refining the crude metal. But just now we have only to do with crucible melting. It only remains to be said that the operation is conducted in the usual manner, and followed by the tilting and drawing out of the ingots, in which there is nothing special to note, so I may as well pass on at once to a more detailed examination of the conversions I witnessed at Langley Mill.

I.—DEPHOSPHORIZATION OF THE PIG.

There were two brands of pig treated—the one from M. de Wendel's blast furnace at Hayanges, in the Moselle; the other from the Baron D'Adelsward's Priory furnaces near Longwy, in the same department. At both works the well-known oolitic ores of the upper lias of this district are exclusively used. The furnaces are worked with coke, and the hot-blast, and at full drift. But the pigs sent to Langley Mill were of totally distinct qualities. The Hayanges brand was a gray foundry pig, large-grained, and very graphitic. In England it would be classed as between No. 1 and No. 2. The Longwy pig was white, verging on the mottled. It may be classed as Forge Pig No. 5. It had been run into moulds and chilled with water. The two pigs were run down by themselves in a common cupola; about ½ per cent. of fluor spar was used as a flux, the better to slag the coke cinders. Samples of the molten metal were taken for analysis before it was run into the converter. These are the results obtained:

	Hayanges gray pig, remelted.	Longwy white pig.	Longwy white pig, remelted.
Silicon.....	3.024	1.050	1.015
Sulphur.....	0.090	0.350	0.333
Phosphorus....	1.275	1.650	1.485

HEATON PROCESS.

I did not look for the other constituents, but I ascertained the presence of manganese and a notable quantity of vanadium in all three samples. The two analyses of the Longwy pig show that the remelting in the cupola has not sensibly modified the composition of the metal. A very slight purification is, however, perceptible.

EXPERIMENTS ON LONGWY PIG.

For each conversion the cupola was charged with 14½ cwt. of pig. The molten metal was not weighed before being run into the converter, but we may reckon upon a waste of 7 per cent. by slagging, burning off, runnings and shell, linings, etc., which would reduce the charge of the converter to 13½ cwt., or even to 13 cwt. 17 lbs., if we deduct a quarter of the residue found in

the cupola after four conversions. To these 665.75 kilos. (13 cwt. 17 lbs.) we must add 120 lbs. for the weight of the perforated plate, 12 lbs. for the two iron bars. The total weight of metal was therefore 725 kilos. (14 cwt. 55 lbs.), of which 720 kilos. (14 cwt. 44 lbs.) were pig, and 5 kilos (11 lbs.) iron. The experiments began with four successive conversions of Longwy pig. The weight of metal was the same in all four, but the charges of nitrate were varied. I will particularize the charges and note the special phenomena of each conversion. First conversion: There was charged into the converter, nitrate of soda, 150 lbs., or 9½ per 100 of the weight of pig; silicious sand, 20.

The molten metal ran very hot into the converter, so reaction was at once very violent; the gases almost immediately kindled at the top of the chimney. The yellow flame lasted two minutes, then appeared the black smoke, which gradually subsided, as did also the ebullition. All was over in four minutes. The nitrous gas was imperceptible. It seemed to be masked by the black vapors and the brilliant sodium flame. In less than a quarter of an hour the purified metal solidified in the converter bottom. It was upset on the hearth and the pasty slags separated. They were opaque and dull, only ¼ cwt. of slag could be separated. The refined metal weighed 639 kilos. (1,405 lbs.), which, when compared with the 725 kilos. charged, would give a total waste of 12 per cent.; but in reality the waste is less, for one should add to the metal weighed the splashes of metal thrown by the ebullition against the lining of the converter, and which are only removed every two or three days. Reckoning them in, the actual waste is reduced to 7 or 8 per cent., but it would be necessary to take the mean of many conversions to be exact. At any rate the analysis of the slag proves that the iron is very little oxidized.

Second conversion: The converter was charged with nitrate of soda, 138 lbs., or 8½ per cent.; quartzose sand, 20 lbs.

The molten metal was not hot enough—the reaction sluggish. The gases at the top of the funnel did not catch fire; the vapors, at first white, then gray, then black, ended with being white. The whole operation lasted 4½ minutes. Nevertheless, the refined metal seemed as fluid as on the first occasion, and presented a similar appearance. It was not weighed. The slag, too, was like that of the first conversion. It weighed 51 lbs.

Third operation: The converter was charged with nitrate of soda, 130 lbs., viz., 8 per 100, quartzose sand, 20 lbs. The molten metal was far too cold, and for 5 minutes there was no reaction. It must have solidified in the perforations of the plate. To start the reaction it was necessary to break the plate by the thrusts of an iron crowbar, worked through the box-funnel of the converter. Even then the reaction was slow, for it lasted six minutes, *i.e.*, 11 minutes altogether from the time the metal was run in. The vapors were very black, neither flame nor nitrous gas was seen to issue from the chimney; nevertheless, the temperature developed was sufficiently high to keep the metal entirely fluid. In the end the conversion succeeded as before, yet one cannot but think that the homogeneity of the product must have been impaired by the low initial temperature. The metal and the slag both resembled the products of the proceeding conversions. The slag weighed 77 lbs. The metal itself was not weighed.

Fourth operation: There was charged into the crucible, nitrate 113½ lbs., viz., about 7 per 100, quartzose sand, 16 lbs. The molten metal was hot. Flames appeared from the first at the base of the converter, and at the end of 2 minutes at the top of the chimney. The whole operation only lasted 3 minutes. As in the preceding experiments, the vapors were hardly at all nitrous. They were very black till the flame appeared. Mr. Heaton considered that this conversion was in all respects normal. The metal and the slag were still the same as in the preceding conversions. Nevertheless, the purification was less complete; the metal, however, was flattened under the hammer at a dull red heat without breaking. Water thrown upon the incandescent metal emitted the odor of sulphuretted hydrogen. As the waste cannot be deduced from any isolated conversion, weighing the metal and the slag was given up.

EXPERIMENTS ON HAYANGES PIG.

The Hayanges pig was treated like the Longwy pig, only that the charge of nitrate was increased. The proportion of sand was also augmented; in reality, as

we shall see, it ought to have been entirely suppressed on account of the 3 per cent. of silicon in the pig. This high percentage of silicon shows itself by a greater intensity of action, and by the increased temperature of the metal. The ebullition and the projections were more violent. The red nitrous fumes were no longer masked by the black smoke. The slag was more abundant and more silicious, and for that reason less rich in phosphoric acid. The purification was less perfect, and one could already see that the dephosphorization is in general less complete in the presence of an excess of silicon, or at any rate that it would be necessary to use a much stronger dose of the nitrate to attain the same result. To calculate the weight of metal converted, I will assume, as before, a waste of 7 per cent. in remelting; and, further, 72 lbs. per conversion must also be deducted for the weight of metal found in the cupola at the end of the day's work.

Fifth operation: The cupola was charged with 1,626 lbs., which, allowing for the 7 per cent. of waste, gives 685 kilos. There are 72 lbs. more to deduct for the residue found in the cupola.

There remains, then, 652.4 kilos., equal to 12 cwt. 3 qr. 10 lbs.; to which must be added for the perforated plate, 54.4 kilos., equal to 1 cwt. 8 lbs.; pig metal and sound iron bars, 5.4 kilos., equal to 19 lbs. There was charged into the nitrate chamber: nitrate, 148 lbs., viz., 9.4 per cent.; quartz sand, 23 lbs.

The molten metal ran hot into the converter, and the reaction took place at once. A great volume of yellow vapor was emitted; in one minute the smoke became black, thirty seconds afterwards it took fire; the light was brilliant and of a bright yellow, the roar intense. That lasted thirty seconds, then the flames went out, the vapors became white and rapidly decreased; all was over in two minutes. The mass of metal was extremely hot and fluid, the nitrate chamber was not detached for thirty minutes; nevertheless, both metal and slag were still fluid. The slag could be drawn out like glass into thin threads of a fine emerald green; small sparks of iron in combustion, such as are produced when cast-steel is run into ingot moulds, disengaged themselves from the metal with jets of yellow flame; the refined metal was not entirely solidified till an hour after the metal had been run into the converter. Thanks to the great heat developed, the two wrought-iron bars which lay on the perforated plate had entirely disappeared, while in the experiments on Longwy pig some portion of them had always been found simply incrusted in the mass of refined metal. This operation produced: Refined metal, 1348 lb.; splashes of metal in the converter, 80 lbs.; total, 1,428 lbs. The waste was, consequently, 1.9 per cent. of pig converted. The slags weighed 253 lbs. They were vitreous when broken, showing a conchoidal fracture, and black in bulk, but of a fine dark-green color in thin chips. They contained globules of metal. The refined metal was vesicular, silvery white, as usual; but its hardness and its crystalline appearance denoted an insufficient dose of the oxidizing agent, which subsequent analysis has confirmed. It was for this reason that the proportion of nitrate was increased in the following experiments:

Sixth conversion: There was charged into the converter: Remelted pig, 1,438 lbs.; perforated plate, 120 lbs.; total of pig, 1,558 lbs.; wrought iron bars, 12 lbs.; total, 1,570 lbs. The nitrate chamber was charged with: nitrate, 170 lbs., or 77 kilos., viz., 10.8 per cent.; quartzose sand, 21 lbs., or 9 kilos. The molten metal came out of the cupola at a low temperature in consequence of an accident to the fan blast. The action was at first imperceptible. There was but a slight emission of white vapor, resulting, no doubt, from the moisture of the nitrate. At the end of one and three-quarter minutes, however, there was a faint exhibition of nitrous fumes. In two and three-quarter minutes the gases kindled in the converter itself, but the flames did not reach the top of the chimney; the nitrous fumes were still perceptible. At three and a quarter minutes these yellow fumes were still stronger; there was an intense roar. In four and a quarter minutes the slag was projected through the box-funnel of the converter, and the ebullition was violent. The flame in the converter went out, and at the same moment the yellow smoke became black. In four and three-quarter minutes the vapors became first lighter in color, then white. In five minutes all was over. In spite of the relative slowness of the conversion, the heat

developed seemed as great as in the first experiment. The metal was hot; it took an hour for the mass to solidify, and, as usual, it gave out jets of yellow flame. The slag was "thready," and just like that of the preceding conversion; it weighed 255 lbs. The weight of refined metal was 1,475 lbs.; the splashes adhering to the lining of the converter, 80 lbs.; total 1,553 lbs., or 703.5 kilos. The waste would, consequently, appear to be only 7.6 kilos., or less than 1.1 per cent.—a result which is evidently wrong.

The splashes attached to the interior of the converter could not have been evenly distributed among the three conversions, or the crane ladle must have been fuller than usual. The actual waste, as I have said before, can only be calculated from the mean of many conversions and from the chemical analysis of the slag.

Seventh conversion: The charge, as in the previous conversion, was: pig-iron, 705. kilos., equal to 13 cwt. 3 qr. 14 lbs.; wrought-iron, 5.4 kilos., equal to 12 lbs.; nitrate, 200 lbs., equal to 96.6 kilos. (12.7 per cent.); sand 24 lbs., equal to 10.3 kilos. The molten metal was hotter than on the second conversion, not so hot as in the first. The phenomena I noted were as follows: abundant nitrous fumes appeared from the very first, but presently slackened. In one and a quarter minutes there was a lively emission of yellow gases and strong projections of slag and metal through the box funnel of the converter. In two and a quarter minutes the gases kindled at the top of the chimney. The flame lasted half a minute, all was over in three minutes. The metal was very hot, very fluid. The slag as before. It weighed 210 lbs. The converted metal was not weighed.

Eighth conversion: The charge the same as in the last, to wit— pig and iron, 711.1 kilos., equal to 13 cwt. 3 qr. 27 lbs.; nitrate, 90.6 kilos., equal to 1 cwt. 86 lbs.; sand, 10.9 kilos., equal to 23 lbs. The molten metal ran out moderately hot. There was little difference in the progress of this conversion and the last. Nitrous fumes were disengaged at once, though faintly at first. In one minute there was a partial combustion of gases in the interior; there were some projections, and the smoke soon became black. In one and a half minutes the smoke kindled at the top of the chimney, there was a deafening roar, abundant projections, and the flames exceedingly brilliant. In two and a half minutes all was over. Then, as usual, there was nothing more visible but a faint white vapor.

The metal remained a long time fluid. It was still so after forty minutes, when the nitrate chamber was detached from the converter, and it was a whole hour from the commencement of the conversion before it could be turned out on the floor of the foundry. The converted metal weighed 1,458 lbs. (equal to 660 kilos.), the slag 252 lbs. (equal to 123 kilos). Consequently the waste would be 134 lbs., or 7.2 per cent. The metal and the slag looked like the products of the last conversion.

We cannot calculate the mean waste on the four conversions, not having the weight of the converted metal in the third. But, taking the weight of the first, second, and fourth, we find—pig treated, 2,134 kilos., equal to 4,694 lbs.; refined metal resulting, 2,010.5 kilos., equal to 4,222 lbs.; waste, 124.5 kilos., equal to 273 lbs.; say 6 per cent. And this, as we shall see, agrees pretty nearly with the results obtained by calculating the iron in the slags. Before we pass on to describe the conversion of the crude product into steel or iron, let us add that the Cleveland brands, of which we saw many charges treated in the Heaton converter, are to be classed between the two extremes we have been dealing with.

They are less graphitic than the Hayanges pig, but grayer than the Longwy pig. And so the reactions in the converter are also intermediate. The vapors, before they kindle, are less nitrous and less black, but they are pretty black too. The slags are more vitreous and silicious than those of Longwy; more opaque and dull than those of Hayanges. In fine, the reactions in the Heaton converter depend, above everything, as is the case in the Bessemer process, on the proportions of silicon. But the progress of the conversion depends also on the initial temperature of the molten metal, and on the degree of care which is taken in the arrangement of the nitrate chamber.

II.—CONVERSION OF THE REFINED METAL INTO WROUGHT-IRON.

The refined metal is converted into malleable iron, as I said before, by a sort

of rapid puddling, continued long enough. In the production of balls, part of the refined metal resulting from the four conversions of Longwy pig was so treated, and from three out of the four conversions of Hayanges pig. Here are the particulars of the experiments in question.

(1.) *Malleable Iron of the First Conversion (Longwy Pig).*—A charge of 392 lbs. (177.5 kilos.) was converted in less than three-quarters of an hour into four balls, one of which was hammered into blooms, and three others hammered and rolled into flat rough bars. Their total weight was 312 lbs., so the waste was 79 lbs., or 20 per cent. A second similar charge gave five rough bars, with a waste of 20½ per cent. A bloom from the first charge was reheated to a welding heat, then rolled into flat merchant bars of 3 in. by ⅜in. (No. 1.)

The three rough bars of the first charge were cut up, faggoted, piled, and rolled into merchant bars of 2 in. by ⅜ in. (No. 2.)

The five rough bars of the second charge were likewise cut up, faggoted, and piled; but these were rolled into small bridge rails, of which the transverse section was about 2 in. (No. 3.)

The waste in the piling was not determined, but we may take it to be the usual average—say 10 per cent.

I will presently give the result of the tests to which these bars were submitted. At present I will only observe that the bars of the first charge were evidently over-puddled. The fracture, lamellar and foliated, shows burnt iron. The rail, after being nicked, broke at the first blow. Its being over-oxidized was at the time attributed—wrongly as we shall see—to an overdose of nitrate. This is why the charge of nitrate was diminished in the subsequent conversions. The rough bars were cracked in the edges.

(2.) *Malleable Iron of the Second Conversion of Longwy pig.*—A first charge of 259 lbs. was treated in 30 min. Each hammered bloom was returned to the furnace for 5 min., and then hammered a second time, then reheated to a white heat—they were rolled into bridge rails like the former. (No. 7.) The rails are clean, without cracks, and when cold bear without fracture repeated blows of the sledge. One of them, hammered till it broke, did not give way till its two halves were brought to an angle of 75 deg. The fracture was fibrous, but the fibres were rather short.

A second charge of the same weight was heated in 25 min. It was then hammered and rolled into rough plate, which showed more cracks than the bars of the first conversion. The rough iron so produced was cut up, faggoted, piled, and rolled into bridge rails. (No. 4.) One of these rails, tested, till it gave away, by the sledge, did not break till its two ends were brought to an angle of 75 deg. The fracture was fibrous, but the fibres were rather short.

A second charge of the same weight was treated in 25 min. It was then hammered and rolled into rough plate, which showed more cracks than the bars of the first conversion.

The rough iron so produced was cut up, faggoted, piled, and rolled into bridge rails (No. 4.) One of these rails, tested till it gave way by the sledge, did not break till its two ends were bent double.

(3.) *Malleable Iron of the Third and Fourth Conversions of Longwy Pig.*—Part of the refined metal of the third and fourth conversions was converted into bridge rails after the manner of the last-mentioned charge (5 and 6). The rails so obtained by ordinary faggoting and piling were like the piled rails of the second conversion, but their fractures were less fibrous. The refining did not seem thorough; the fractures showed a certain lack of homogeneity.

(4.) *Malleable Iron of the Fifth Conversion (Hayanges Pig).*—257 lbs. of refined metal of the fifth conversion was treated in the puddling furnace. Part of it was made into two blooms, which were reheated to a white welding heat, then rolled into bridge rails. They showed some cracks, which were sure proof of incomplete purification. Part of it was treated in the usual way—the rough bars were cut up, faggoted, piled, and rolled into flat bars of 2 in. by ⅜ in. (No. 8.)

(5.) *Malleable Iron of the Sixth and Eighth Conversions (Hayanges).*—Some cwts. of the refined metal of the sixth and eighth conversions were treated in the same way. By faggoting and piling, some flat rolled bars were produced of 2 in. by ⅜ in. (Nos. 9 and 10), and some square hammered bars of ½ in. square (No. 12).

Two bars of the eighth conversion were

also hammered into blooms, and reheated to a white welding heat without piling. After this reheating one of them was drawn out under the hammer into $\frac{1}{2}$ in. square bars (No. 13); another rolled into flat bars of 2 in. by $\frac{3}{8}$ in. (No. 11). I pass rapidly over these details because, as I have already said, I do not think the Heaton metal can profitably be worked up into malleable iron. The nitrate purification is too costly, and the waste in balling and blooming too great.

Besides, the quality of the iron produced was not all that could be desired: but at the same time it must be remembered that in these experiments the percentage of nitrate used was, to some extent, settled at hap-hazard, and in every instance without any preliminary analysis of the pigs, and moreover the puddlers knew nothing of of the material they were dealing with. The tenacity of the bars was roughly tested by their resistance to the blows of a sledge, as before stated, but was more accurately determined at Mr. Kirkaldy's well-known establishment in London.

III. BREAKING TESTS OF THE IRON.

The iron bars were all tested just as they arrived from the works. The length submitted to tension was 10 in. I sum up the results in the following Table, which contains, besides the English figures, a column showing the breaking strain in kilos. to each square millimetre of the original section. The numbers of the experiments correspond to the figures in brackets which follow the account of each conversion.

Table of the Tension Tests of the Malleable Irons made from the Longwy and Hyanges Brands, compiled from Mr. Kirkaldy's Tables.

Description of Bars.	Dimensions in inches.	Original section of bars in square inches.	Breaking strain. (Original area).		Comparison of the area of fracture with original area.	Percentage of elongation.	Observations.
			Tons per square inch.	Kilos. per mil imetre sq.			
No. 1. Longwy flat bars, not piled. Mean of six bars from the first conversion	3×$\frac{3}{8}$	1.125	18.7	29.4		7.0	Fibrous fracture.
" 2. Longwy flat bars, piled	2×$\frac{3}{8}$	0.768	19.3	30.4		7.4	Ditto.
" 3. Longwy, conversion No. 1, bridge rail	"	2.08	19.3	30.4		9.0	No. 3 to 6, experiments on a single rail; all four rails rolled from the crude iron piled. Fracture, half fibrous, half crystalline.
" 4. Longwy, conversion No. 2	"	2.08	19.9	31.3		10.8	
" 5. Longwy, bridge rail, conversion No. 3	"	2.08	19.0	29.9		8.6	
" 6. Longwy, bridge rail, conversion No. 4	"	2.08	19.6	30.8		10.6	
" 7. Bridge rail of conversion No. 2, rolled, not piled	"	2.08	18.8	29.6	Not determined.	7.1	Half fibrous, half crystalline.
" 8. Flat bars, piled, Hayanges, conversion No. 5. Mean of four bars	"	0.768	21.1	33.2	0.84	10.1	Fibrous.
" 9. Flat bars, piled, Hayanges, conversion No. 6. Mean of four bars	"	0.768	22.2	34.9	0.77	15.3	"
" 10. Flat bars, Hayanges, No. 8, piled. Mean of four bars	"	0.713	20.5	32.3	0.85	12.3	"
" 11. Flat bars, not piled, Hayanges, conversion No. 8	"	0.768	21.6	34.0	0.86	6.1	"
" 12. Square bars, Hayanges, conversion No. 8, piled and tilted. Mean of four bars	$\frac{1}{2}$×$\frac{1}{2}$	0.278	23.1	36.4	0.77	13.9	"
" 13. Square bars, but not piled. Mean of four bars	"	0.278	27.5	43.3	0.81	10.8	Half fibrous, half crystalline.

What are we to conclude from this Table? If we only took into consideration the breaking strain (*i. e.*, the statical breaking strain), we might say that the strength of the Longwy malleable irons, prepared by nitrate, was about the same as that of common iron of equal dimensions; and that the bars Nos. 12 and 13 approximate even to high-class irons. But this datum does not in itself suffice to determine the value of a metal for the work it is called upon to sustain. Harsh and brittle irons are equal, if not superior, to the best soft irons in this respect. It is their dynamic resistance which we must attend to; that is to say, the "work" of the bars submitted to strains within their elastic limits. In default of these data, which are wanting, we should at any rate arrive at a more precise criterion of the value of the iron, compare the elongation and the breaking load, or, as Mr. Kirkaldy proposes, compare this load, not with the original section, but with the section at the fracture.*

From the numerous experiments tabulated by Mr. Kirkaldy, we may arrive at the results embodied in the following Table :—

Bar Fronts.	Breaking Strain (Fractured area).		Breaking Strain (Original area).	
	Kilos. per mill-sq.	Tons per square inch.	Kilos. per mm. sq.	Tons per square inch.
Swedish malleable iron, Ekman & Gothenburg†	100 to 112	54 to 67	33 to 35	21
‡Fagersta homogeneous iron for fine wire	125 to 141	83 to	32 to 38	22
Lowmoor iron	90 to 100	51 to 58	40 to 45	25 to 29
Staffordshire best	80 to 88	42 to 45	41 to 43	25 to 28
Scotch B. B	60 to 70	35 to 40	42 to 46	26 to 29
Scotch common	50	24	42	26

On comparing the figures of these two columns, we see that by the first, Swedish malleable iron quite heads the list, while by the second it would be classed below even the common Scotch. We see also that by the figures in the second column, the justly celebrated Lowmoor iron would be no better than the common Scotch. To determine the value of the irons, we must, therefore, above all, consider the breaking strain with reference to the area of fracture. Well, if we calculate the breaking strains of the Moselle flat bars, of which we know the areas of fracture, we shall arrive at the following figures:

Nos. of the bars.	BREAKING STRAIN. Kilos. per sq. millimetre.	Tons per sq. in. (Area of fracture).
No. 8, of the 5th conversion	39.3	25
" 9, " 6th "	43.3	27
" 10, " 8th "	37.9	20
" 11, " 8th "	39.6	25
" 12, square piled bars of the 8th.	47.3	29
" 13, square bars of the 8th, not piled	53.2	34

Comparing these results with the preceding ones, we see that the Hayanges irons, prepared by the nitrate process, may be classed with the ordinary Scotch irons. The same conclusion may be deduced from the "elongation" column. Swedish iron and good English irons elongate, before fracture, to the extent of from 25 to 30 per cent. of their original length, while the elongation of the common Scotch iron does not exceed 10 or 12 per cent., and is sometimes as little as 6 or 7 per cent., which, according to the Table on page 32, is about the average elongation of the Moselle irons, ranging from 6 to 15 per cent. These irons are consequently of "ordinary quality." They are soft and elongate but little under tension—more especially the Longwy irons, whose elongation is even less than those of Hayanges. Ought we to attribute this inferiority of the Longwy irons, and, in general, the medium quality of these nitrate-treated irons, to the inefficiency of the new refining process? I think not. We have

* Mr. Edwin Clark, in his work on the "Britannia and Conway Tubes," has shown that a bad boiler-plate, very brittle and crystalline, can stand 22 tons to the square inch, but without any elongation, while on a mean, good boiler-plates will only stand 19 tons, but with elongations which vary from 5 to 12¼ per cent.

† Swedish malleable iron contracts before breaking in the proportion of 100 to 30 and 25. Lowmoor iron in the proportion of 100 to 47, and common Scotch iron in the proportion of 100 to 85.

‡ Fagersta figures extracted from Mr. Hewitt's report.

already seen that in the case of the Longwy iron, the puddling or reheating was badly done. The irons were burnt. The decarburization was carried too far, as we shall see. Besides, the fracture of the bars denotes an iron which is hardly homogeneous; we see specks dark-colored and dull, which show that the slags are not sufficiently expelled. The heats have been insufficient, and the gases of the furnace too oxidizing.

Mr. Kirkaldy's table of experiments on the nitrate-treated Moselle irons prove, too, that piling has effected no improvement. Further, if bars Nos. 12 and 13 show more tenacity than the rest, this is attributable to their smaller size and to their having been hammered. We know that hammered irons are stronger than rolled irons, and that their strength increases in inverse ratio to the section of the bars.

IV. CONVERSION OF THE REFINED METAL INTO CAST-STEEL.

Cast-steel has been hitherto made at Langley Mill, as we before said, by simple reaction in the crucible. The crude metal is hammered, at a low red heat, into thin discs, called "cake," which are broken up and classed according to the grain, like cemented steel, into numbers indicating their degree of hardness. These cakes are mixed in the crucible with more or less malleable iron and spiegeleisen, according to the product it is desired to obtain. The malleable iron regulates the degree of hardness; the spiegeleisen, by its manganese, finishes the refining process. A part of the metal refined in the seven last conversions was thus treated. Here are the details of the operations: Steel of the second conversion of Longwy pig. Two crucibles were charged, each with 33 lbs. of converted metal in cakes, and 12 lbs. of malleable iron from the first conversion; spiegeleisen of Siegen, three-quarters of a pound. Each crucible produced an hexagonal ingot of 2½ in. in diameter. The melting took four hours. The steel was very fluid, and showed little tendency to rise. The fracture of the ingot showed large grains, and indicated soft steel, which agrees with my analysis of the carbon, which, according to the Table I shall presently give, will be seen not to exceed 0.0036. The ingots were tilted under the hammer at a low red heat, without showing any cracks. The grain of the tilted bars was fine, homogeneous, light gray, but rather shiny. The skin was quite smooth. Six ½ in. square bars were sent to London to be tested by tension at Mr. Kirkaldy's. Other bars were sent to Longwy to be tested as tools under the eyes of MM. d'Adelsward. Cutting tools, turning tools, and cold chisels were made out of them. When tempered in the ordinary way, the edges of the cutting tools give; when highly tempered, the tool stands, but the cold chisels have a tendency to chip under concussion. It is not high-class steel; it is not thoroughly purified. A pure steel, containing only 0.0036 of carbon, would not temper. If it tempers, notwithstanding this low percentage of carbon, it is because it contains other ingredients. We shall find in it silicon and phosphorus as well as carbon. Yet, as common Bessemer steel contains also foreign ingredients, it is not impossible but that it may be useful for rails and plate iron. It only gives way under a tension strain of 49.5 tons per square inch, with an elongation of 12.5 per cent.

II. STEEL FROM THE THIRD CONVERSION OF LONGWY PIG.

The crucibles received the same charge as before, and an ingot was run from each crucible. The grain was finer, closer, the blow-holes less numerous. The steel was, in fact, more carburized (0.0055 carbon instead of 0.0036). When too highly heated, it showed symptoms of cracks, but sound bars of ½ in. square were readily obtained, and when made into tools, gave results very similar to those obtained from the second conversion. Their tenacity, however, was greater—viz., 52 tons instead of 49 tons per square inch, as was to be expected from their higher degree of carburization. But the bars elongated less before giving way, and this indicates a certain degree of shortness, certainly attributable to foreign ingredients. The elongation is reduced to 4 per cent.

III. — STEEL OF THE FOURTH CONVERSION OF LONGWY PIG.

There was charged into the crucibles: Refined metal in cakes 30 lbs.; malleable iron from the first conversion, 15 lbs.; spiegeleisen, ½ lb. The ingots resembled the steels of the second conversion. In spite of the smaller percentage of nitrate,

the percentage of carbon was the same (0.0033 to 0.0036), in consequence of a larger proportion of malleable iron having been used in the crucible. But the purification was less advanced, the steel less pure. The breaking strain, indeed, is little less than that of No. 2, but the diminished elongation (only 6 per cent. instead of 12.5 per 100) shows the presence of foreign elements. The tools blunted when slightly tempered, chipped when highly tempered. This experiment, when compared with the results of the second conversion, proved that to obtain sound steel, it would be better to increase the charge of nitrate in the converter so as to purify more thoroughly, and the charge of malleable iron in the crucible unless we were to recarburize the metal, as in the Bessemer converter, by a larger addition of good spiegeleisen.

We should also remark that the ingot of the fourth conversion is no more "true steel" than that of the second; at any rate, it is not carburized steel, for 0.0035 to .0036 of carbon is not sufficient to convert iron into steel. It is homogeneous iron, which hardens in water, thanks to the silicon and phosphorus it retains; but this impure iron, slightly carburized, has less body than true steel. It resists slow tension, but yields to a sudden shock, and elongates but little.

IV. — STEEL OF THE FIFTH CONVERSION OF HAYANGES PIG.

There was charged into the crucible: Refined metal in cakes, 34 lbs.; malleable iron made from the refined metal of the same conversion, 14 lbs.; spiegeleisen ¼ lb. The ingots on fracture denoted by their large grains a steel containing little carbon. They forged easily at a low red heat, but some few cracks were visible at the first heating. To obtain a steel more free from foreign ingredients, charges of the following composition were melted in five crucibles:—Cakes, 30 lbs.; malleable iron, 14 lbs.; spiegeleisen, ½ lb.

The 5 charges were run into a single mould for an ingot of 2 cwt.. This large ingot was to be rolled into rails at Hayanges. It was sent, but the trial did not take place in consequence of the rolling mills not being adapted for rolling steel. The small ingots from the two first crucibles were tilted into ½ in. bars, and tested by tension at Mr. Kirkaldy's. The mean of the four bars showed a breaking strain of 80 kilos. per millimetre sq. (51 tons per sq. in.), but the elongation was only 3.1 per cent. The metal was shorter than that of the preceding bars. Its percentage of carbon is 0.0037. It is therefore not true steel, but homogeneous iron, more or less hardened by its phosphorus and silicon. The tools made at Hayanges from the first ingots blunted on hard pig, even when hard tempered. So in the matter of hardening in water, as in the matter of dynamic resistance, phosphorus is but an imperfect substitute for carbon.

V.—STEEL OF THE SIXTH CONVERSION OF HAYANGES PIG.

Two ingots were made as follows: refined metal, 34 lbs.; malleable iron of the the same charge, 14 lbs,; spiegeleisen, ¼ lb.

The fracture of the ingots showed a metal very slightly carburized. The tilted steel only retained .0032 of carbon. When hot the metal worked easily, and it was tilted without cracks; but the cutting tools made of it blunt more easily than those of the fifth conversion. It is therefore simply homogeneous iron, hardened by phosphorus, not steel. Some bars of ¾ in. sq. were tested by the tension strain. The mean of four bars was 59.3 kilos. per sq. millimetre (37.8 tons per sq. in.), with an elongation of 1.3 per cent. That is less than the bars of the fifth conversion, in spite of the increased charge of nitrate; but here the difference arises chiefly from the larger dimensions of the bars. Their transverse section is twice as large. A third ingot of 2 cwt. was run from the united charges of five crucibles, made up as follows: cakes, 30 lbs.; malleable iron, 15 lbs.; spiegeleisen, ½ lb. This large ingot, like its predecessor, was to be rolled into rails, but this has not been done, for the reason above given.

VI.—PRODUCTS OF THE SEVENTH CONVERSION OF HAYANGES PIG.

The refined metal of the seventh conversion was to be treated in Mr. Heaton's own patent furnace, but it was entirely scorified by the injudicious arrangement of the furnace.

VII.—STEEL OF THE EIGHTH CONVERSION (HAYANGES PIG).

Eight crucibles were charged with: cakes, 30 lbs.; malleable iron of the same

conversion, 15 lbs.; spiegel, ½ lb. The fractures of the ingots were finer-grained than before; the steel forged easily. Turning tools and cutters made of it stand fairly when moderately tempered, but chip if over-tempered, and blunt if insufficiently tempered. This was the most highly carburized of the three steels made of Hayanges pig. I found it to contain .0048 of carbon, and even .0062 in the ingot. That is the line of demarcation between steel and hard iron.

The experiments as to breaking strain on four ½ in. square bars gave about the same results as the sixth conversion. They broke under a mean load of 79.2 kilos. per sq. millimetre (50.3 tons per sq. in.), with an elongation of 3.2 per 100. That is still a steel, or hard homogeneous iron, lacking "body." We see that the Hayanges steels elongate less than those of Longwy. Now their analyses clearly prove, as we shall see, that this is due to their larger percentage of phosphorus, and that, *cæteris paribus*, the dephosphorization is the less complete as the pigs are the more silicious.

(TO BE CONTINUED.)

IRON AND STEEL NOTES.

STEEL RAILS.—At the recent meeting of the Iron Steel Institute, held at Middleboro', some valuable and practical information was given on the subject of the manufacture of steel and its adaptation to rails. Mr. Edward Williams said that it has been too much the habit to assume that there is antagonism between those who make rails and those who use them, and that the former desire only to make cheap rails, however bad, and that the latter interpose difficulties and onerous stipulations without reasonable cause. He believes this view to be entirely incorrect, and that, on the contrary, the great majority of engineers and ironmakers alike are, in their several ways, striving after the same end—namely, rails of high quality at the lowest price possible. The rails of to-day are of two distinct kinds—those made from ingots and those built up; and he admits that, the question of cost and possible supply not considered, ingot made rails are the best. He holds it incorrect to describe the two kinds as steel rails and iron rails, because the Bessemer rails now making have a percentage of carbon much lower than that of steel proper, as it used to be known. Besides, as far as he knows, it is impossible to define where iron ends and steel begins. It would be as well, therefore, to call the two divisions ingot rails and piled rails. He has come to the conclusion, unwillingly, that they could not succeed in producing puddled, workable, and welded solid blooms; and as far as present knowledge extends, ingots cheap enough to make rails on a considerable scale are only to be obtained by the Bessemer process. Whether or not the Siemens-Martin process can compete in point of cheapness of production with the Bessemer process is as yet unproved; but it is sufficient to know that both can without doubt produce ingots that roll into rails without much difficulty; and that such rails, being free from the possibility of lamination, must be more enduring than built-up or piled rails, however carefully made. If the phosphorus difficulty can be got over—and Mr. Williams thinks it can—and if the cheap pigs of the Cleveland district were available for the Bessemer process, there would be so great a reduction of cost that ingot rails would be almost as cheap as piled rails, and the latter must at once give way; but there is not at present any good ground for expecting that such a change is near. The removal in February next of the bulk of the present Bessemer royalty charge will no doubt reduce the selling prices of ingot rails; but the author of the paper was mistaken if, after all, they could be produced so as to be sold within 40s. or 50s. per cent. of the average selling price of good piled rails, the life of which in the ordinary operations of a heavily worked railway would be about 15 years. For very severely worked places ingot rails, at almost any moderate extra price, were of course the best. Strenuous efforts had been made by nearly all the great iron makers to produce steel-topped rails, which, it was hoped, would be made much more lasting than the usual piled iron rails, and less costly than ingot rails. Puddled steel seemed to offer a cheap and good material for this; and after some difficulty to begin with, it was produced of very uniform quality. It was no doubt a material capable of resisting well the wear and tear of railway stock; but it could scarcely be welded at all, and as it could not be obtained in solid blooms for rail sizes, the system failed, and had been abandoned—in this country at least—entirely. That Bessemer steel slabs could by great care and skill be so fastened to iron as to make rails was proved by the instance of the rails supplied to the Edinburgh and Glasgow Railway, and to the Swedish Government. He, however, did not expect to find such rails come into general use, because of the difficulty of welding in the steel slab, which was not much, if at all, less than puddled steel. So far as he could see, the only choice lay between the ingot and the piled rail, and in the uncertainty as to the Siemens-Martin process, it might be assumed that the Bessemer process would supply the former. He did not advocate the discontinuance of the system of testing rails. But to meet the severe tests, it was absolutely necessary to use fibrous iron, and not to heat it too much. He had thought and experimented much upon the subject, and was satisfied that fibrous nature and weldability did not go together, and that only well-piled crystalline iron welded easily, and therefore with moderate certainty. It was undesirable, he thought, to use rail piles of great sectional area, which were less likely to be tested equally at the centre than the small piles of a quarter of a century ago. The two great rail-producing districts of this country were Wales and the North of England, and each had a system of working different from the other. The Welsh system had the merit of more work on the iron—that is greater consolidation—than was obtained by the North of England system. That was a doubtful advantage, if it was true, as he believed, that the iron for rails was, as a rule, too much worked, while it had the demerit of having

many through welds on the heads of the rails. The North of England system produced hard crystalline heads, with the fewest possible welds; and when the iron of the district was not too much worked, and thus made fibrous, it was of the most weldable character, though somewhat brittle. Such iron, it seemed to him, was likely to produce enduring rails, and he firmly believed that, with proper attention, piled rails could and would for a long time yet be made from it, capable of competing successfully with good ingot rails produced by the Bessemer process.—*The Railway News.*

MANUFACTURE OF IRON AND STEEL BY THE NITRATE PROCESS.—Mr. J. P. Budd, of Ystalyfera, near Swansea, has recently patented an invention which has for its object to subject molten cast-iron to the action of nitrate of soda and soft hematite iron ore or other oxide of iron, previous to its being subjected to the puddling process. For this purpose he runs the molten cast-iron into shallow pans capable of holding from 3 in. to 5 in. in depth of melted metal and lined with a paste composed of the above-mentioned materials. When the fluid metal is poured into the pans a violent ebullition takes place, and a large proportion of the silica, together with some of the carbon, phosphorus, and sulphur contained in the iron, is carried off in the slag, so that when the slabs of purified metal are subsequently worked in the puddling furnace, the puddling operations are effected much more rapidly than with ordinary pig iron, as when puddling ordinary pig iron in a puddling furnace but a very small proportion of carbon is separated from the iron before the greater proportion of the silica is eliminated. Cast-iron, if of a suitable quality for steel making, may advantageously be acted on by a paste containing nitrate of soda or hematite ore, or both combined, in shallow pans, as above described, previously to being decarbonized to convert it into steel.

When the object is to produce bars of wrought iron which are to be rolled into black plate or thin sheet iron, to be afterwards converted into tin plate, Mr. Budd lines the shallow pans into which the cast iron is run with a composition composed of hematite iron ore and nitrate of soda. He mixes together a quantity of hematite iron ore, containing, if possible, no phosphorus or sulphur, and only a moderate quantity of silica, and mixes therewith half by bulk or two-fifths by weight of nitrate of soda, or 30 lbs. of hematite ore to 20 lbs. of nitrate of soda. Having well mixed these together mechanically, the mixture is passed through a pair of clay rolls, by which the grit is reduced, and it becomes more plastic. A paste is then formed of the mixture which requires about three-tenths of its weight of water to be added; it is then sufficiently liquid to be filled into a bucket. A series of shallow moulds of cast-iron are then placed as near as convenient to the tapping hole of the blast furnace from which the fluid cast iron is to be obtained. Those found convenient are of the following dimensions:—Length, 7 ft. 9 in. at top tapering to 7 ft. 4½ in. at bottom; width, 2 ft. 2 in. at top tapering to 1 ft. 9½ in. at bottom; depth, 4 in. The use of the bevelling or tapering in the mould is, that the plate of cast-iron shall be more easily removed from it. These moulds hold about 13 cwt. of cast-iron when filled about 3½ in. deep. Into these moulds molten cast-iron is run every 4 hours or oftener, care being taken to fill them often enough that they shall retain their heat or drying power between the casts.

As the casts from the furnace must thus be frequent the iron is potted from the furnace—that is, the operator takes out what iron he requires from an opening into the furnace at the upper part of the tapping hole without emptying the whole of the iron in the half. Whilst the moulds are hot from the previous cast he pours into each of them a bucketful, or about 64 lbs., of the refining mixture before described, and spreads it evenly over the bottom and sides. The water evaporates, and the mixture lies at the bottom as an adhering paste. The workman then proceeds to run the molten iron from the furnace until he has filled the moulds about 3½ in. A great ebullition takes place, fumes in large quantity are evolved, jets of flame burn from the surface of the metal for a considerable time, a quantity of scoria is thrown up violently to the surface and separates from the plate of iron that fills the mould, and when cold can be stripped therefrom. The weight of the scoria so thrown up is from 30 lbs. to 40 lbs. from each plate of metal weighing about 13 cwt. The iron contained in the hematite ore used in the paste is converted into cast-iron, and adheres to the bottom of the plate. The refined iron when broken presents a honeycomb or cellular appearance throughout, and resembles overblown refined metal, and a large proportion of the silica will have been removed from it. The iron thus refined is ready for the puddling process.

As advanced refined metal Mr. Budd finds it advantageous to use some pig iron with the iron refined as above in puddling; about one-third of pig iron answers best. Cast-iron thus refined, even if it be what is commercially known as cinder pig, which is produced when iron scoria are largely used as material in the blast furnace, will make excellent puddle bars and work to a good yield. The process of puddling is shortened, and the sides and the bottom of the furnace are less acted on than with unrefined iron. The quantity and proportions of the refining paste which we have given are suitable for the quality of cast-iron known as white iron. When grey or carburetted iron is used the quantity of nitrate of soda to be used with the hematite ore should be increased; about 30 lbs. of nitrate of soda (instead of 20 lbs. as in the composition first mentioned) being used with 30 lbs. of hematite ore.

When the malleable iron sought to be made in the puddling furnace is not to be of the quality suitable for tin bars and similar purposes, but is required to be a softer working quality suitable for rails and merchant oars, Mr. Budd does not use nitrate of soda in the refining paste, but makes it of hematite ore alone. When used alone a great ebullition takes place when the molten iron runs over it, the oxide of iron in the hematite is reduced, jets of white flame burn on the surface for a considerable time, and a large proportion of the silica is separated from the iron. The refined iron in this state is much preferred by the puddlers, as it lessens and helps their work. In place of hematita ore other oxide of iron which can similarly be formed into a paste may be employed in place thereof, as, for example, the refuse of iron pyrites from which the sulphur has been extracted for the manufacture of sulphuric acid, and from which the copper and other metals contained in it have been extracted. Oxide of manganese, iron scale, or other substances capable of yielding oxygen

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when exposed to heat may be incorporated with the paste.—*Mechanics' Magazine.*

STEEL-MAKING IN PITTSBURGH.—The manufacturers of Pittsburgh claim the credit of supplying 65 per cent. of all the various grades of steel turned out in the United States. The first essays at its production date 40 years back, but according to the "Pittsburgh Commercial" it is within the last 8 years that the most remarkable progress has been made, which has placed the steel produced there on an equality with the best imported. According to the census of 1860, the six establishments employed in this manufacture, which then existed at Pittsburgh, represented capital amounting to $1,080,000, and their annual products were valued at $888,000, a sum less than the annual sales of a single establishment at the present time. These steel works are now eight in number, and represent an invested capital of $4,500,000, and their annual products amount to nearly as much. According to the assessor's books the sales for the past year have reached the value of $3,956,845, and these being effected during a period of depression show the magnitude of the trade.—*American Railway Times.*

RAILWAY NOTES.

LONDON TO PEKIN BY RAIL.—Let us see what is yet required in order to carry a traveller from London to Pekin. Captain Taylor, in one of his able reports, has insisted that railway travellers will never be satisfied until they can pass dry-shod from London to Calcutta. The first of the missing links is that difficulty of the channel between England and France. That we admit is rather a "big" affair, whether the work be done under or over the water. But if either of these courses should be found to present insuperable difficulties, there is the easy mode of solving the problem by providing spacious steam ferries, which would convey the passengers and luggage-vans with so much ease and comfort that the short sea passage to Calais would come to be regarded as only a portion of the railway journey. We take, therefore, a leap at once across the Channel, and find ourselves transferred from the South Eastern or Chatham and Dover systems to the Northern of France. From Calais we pass on by the existing systems of railways to Belgrade, on the Danube. The system of the Roumelian Railways which have been already planned, and which we explained very fully a few weeks since, will connect Constantinople with the other portions of the European systems of railways. From the Austrian frontier a line will be made, passing through Widin or Nissa, Sophia, Phillipoli, and Adrianople, to Constantinople. The negotiations for providing the capital for this line must sooner or later be brought to a satisfactory termination, and in the hands of a powerful body of capitalists the first stage of the journey across Europe, from Calais to Constantinople—from the Straits of Dover to the shores of the Bosphorus—will be complete. The continent of Europe is crossed—the vaster tracts of Asia now lie before us.

A line of railway through the Asiatic provinces of the Turkish Empire has already been partially surveyed. It would cover the distance between Scutari and the Persian Gulf. The Porte is willing to grant the land gratis, and it would offer to the British Government special securities for the payment of the interest and the sinking fund of the loan necessary to complete the work, if our Government would take the financial responsibility of the undertaking by guaranteeing them a loan, after the precedent of the war loan of 1855. This, no doubt, is a very serious matter. But England guaranteed for Turkey a loan to enable her to carry on the contest with Russia, the whole amount of which was expended in an unproductive outlay in a few months, leaving behind nothing which could advance the prosperity of the country. The loan so guaranteed would have made a railway from the Bosphorus to the Persian Gulf; it was spent in keeping Russia out of Constantinople, and for the purpose of securing that balance of power in Europe which at any day may be overthrown. It may come to pass that some day the statesmen who aspire to govern the world may see that promoting trade and commerce, and assisting production, and promoting the arts of peace, may be as worthy of their consideration as squandering millions in war and in the destruction of life and property. When that reform shall have taken place, the day will be near at hand when an English Government, finding that the canalization of the Isthmus of Suez has brought them into closer competition with other importing States of Europe, will find it to their interest to provide a still more direct communication with its Indian Empire; and to this end they will lend their powerful aid to that system of the Euphrates Valley Railway which has been so often and so vainly pressed upon their attention by Mr. Andrew and others. The distance from Calais to Constantinople would be by rail say 1,700 miles, thence to Bassorah, on the Persian Gulf, about 1,500 miles. From Bussorah to Bunder Abbas, along the level country of the Persian Gulf, would be about 700 miles. From Bunder Abbas to Kurrachee would be by a railway carried along the Mekran coast; the journey would be about 750 miles. The distance between Calais and Kurrachee, about 4,000 miles, would be traversed by the locomotive in 7 days.

At Kurrachee we come into connection with the system of our Indian railways. There is a connecting link required between the terminus of the Bombay and Baroda, and Kurrachee, at the mouth of the Scinde. With this completed, or the extension to Moultan finished, the Indian Peninsula would be provided for, the distance between Kurrachee and Calcutta would be accomplished, and a further 2,000 miles of railway would become available for the great overland journey. At this part of the journey we would take in hand the scheme which Captain Speye has, with so much perseverance, brought before the British public and the Government. From all that has been ascertained of the nature of the country to be traversed, there are no difficulties in the way of carrying out a system of railways through Burmah and Western China to Pekin. At present the Chinese Government are opposed to the introduction of railways. That hostility will sooner or later disappear as the people are brought more into contact with the civilization of the West. The vast population is already swarming over the United States of America. These people have rendered good service in the construction of the Great Pacific Railroad on the American continent, and the accounts which they will give on their return, or by other com-

munication, to their friends and relations in China, must have the effect of forming a public opinion in favor of the introduction of railways into China. For the present, we have our work before us to complete the missing links in Europe and Western Asia. By the time these are supplied the Chinese will be only too glad to aid in forming a portion of the Grand European and Asiatic Railway from London to Pekin.—*Railway News.*

STEEL RAILS AND STEEL-HEADED RAILS.—It has been too much the practice of railway managers to consider only the increased durability of steel. A less striking, but perhaps equally important advantage, is that it has double the strength, and more than double the stiffness of iron. Some three years since, Mr. George Berkely made, in England, above 600 tests of the stiffness of steel and iron rails of equal section. The rails were supported on five feet bearings, and loaded with dead pressure at the middle. The first rails tried weighed 68 lbs. per yard, and loads respectively of 20 tons and 30 tons were applied. The average of 427 tests of the Ebbo Vale Co.'s and two other standard makers of iron rails, gave, with 20 tons, a deflection of $\frac{3}{8}$ in. and a permanent set of $\frac{1}{4}$ in. With 30 tons the deflection was $2\frac{1}{2}$ in., and the permanent set $2\frac{1}{16}$ in. With Brown's steel rails 45 tests gave an average deflection of but $\frac{5}{16}$th in. and a permanent set of $\frac{1}{4}$th in. With heavier rails and loads, the comparative stiffness of steel was more marked. The great and constant resistance to traction, and the wear and tear of track wheels and running gear, due to the deflection of rails between the sleepers and the perpetual series of resulting concussions, may be much reduced, or practically avoided, by the use of rails of twice the ordinary stiffness; in such a case, however, reasonably good ballast and sleepers would be essential. When a whole series of sleepers sink bodily into the mud, the consideration of deflection between the sleepers is a permanent requirement. If the weight of steel rails is decreased in proportion to their strength, these advantages of cheaper traction and maintenance will not, of course, be realized. The best practice here and abroad, is to use the same weight for steel as had been formerly employed for iron. Many attempts have been made in England, on the continent, and in this country, to produce a good steel-headed rail, and not without success. Puddled steel heads have all the structural defects of wrought-iron, as they are not formed from a cast, and hence homogeneous mass, but are made by the wrought-iron process, and are, in fact, a "high," steely wrought-iron. They are, however, a great improvement upon ordinary iron, although probably little cheaper than cast-steel heads. Rolling a plain cast-steel slab upon an iron pile has not proved successful. The weld cannot be perfected, on so large a scale, and the steel peels off under the action of car wheels. Forming the slab with grooves, into which the iron would dovetail when the pile was rolled into a rail, has been quite successful. The greater part of some 500 tons of such rails, made in this country, and put down where they would be severely tested, about four years ago, have outworn some three iron rails. Others failed in the iron stem, which was too light, after a shorter service. Rolling small bars of steel into an iron pile has been recently commenced at various mills in this country and in England. No conclusions are yet warranted by the short trial of these rails. There is a growing feeling among engineers and steel-makers that the compound rail, made wholly or partly of steel, will prove more safe and economical than any solid rail, and that the defects of the old compound iron rail, largely used in this State some years since, may be avoided since these defects were chiefly due to the nature of the material. The experiments in this direction will be watched with great interest by railway managers, for if the same durability can be obtained with a steel cap as with an all steel rail, the first cost will be greatly decreased. A rail made in two or three continuous parts, breaking joints, is also a practical insurance against disaster from broken rails.—*New York State Engineer's Report.*

ORDNANCE AND NAVAL NOTES.

HYDRAULIC BUFFERS.—Col. H. Clerk, R. A., F. R. S., recently read a paper before the British Association upon the effect of water used as a buffer to check the recoil of heavy guns, in which he describes an arrangement for the purpose, submitted by him to the Secretary of War. We find it given in the "Engineer" for October 15th: "It consists of a wrought iron cylinder closed at one end, the other end fitted with a cap and stuffing-box, through which a piston rod passes. The length of the cylinder and piston rod are regulated by the amount of recoil required. The piston fits well into the cylinder, and is perforated with four small holes. The ratio between the diameter of these holes and that of the cylinder is determined by the amount of work required to be performed on the water with which the cylinder is filled, enough air space being left to allow the displacement of water by the length of the piston rod due to the recoil. This air space also acts as an elastic buffer, and takes off the violence of the first impact of the piston on the water. The cylinder is firmly attached to the platform on which the carriage recoils, and the end of the piston rod to the carriage itself; so that on the discharge of the gun the carriage drives the piston through the water with an initial velocity V, whilst the water has to pass through the holes with an initial velocity R V, R being the ratio between the area of the cylinder and of the holes. This buffer has not only been used on shore with guns up to 25 tons weight, but also at sea, with light guns of only $1\frac{1}{2}$ cwt. and 8 cwt. in boats, and lately with 9.in. guns of 12 tons on board H. M. S. Prince Albert, in all cases with equal success.

"In place of water, it has been recommended to use oil, as there is less chance of corrosion taking place if the cylinder is kept full for any lengthened period, and no danger of the fluid freezing in ordinary frosts. The satisfactory manner in which this buffer has worked in checking the recoil of a gun of 25 tons weight leads me to anticipate that it could be usefully applied towards preventing, or diminishing, the destructive effects of a railway collision."

THE "DEVASTATION."—On Friday last the keel of the Devastation, a sister ship to the Thunderer, now building at Pembroke, was officially laid at Portsmouth. The Devastation belongs to the new class of iron-clads without masts or sails, dependent upon their steam power alone, and therefore suited especially for fighting, and not for cruising

ships. When completed, they will be unequalled for defensive powers, for heavy armament, and for the large capacity for carrying coals, which is, indeed, the vital element of their active existence. The London "Times" gives the following particulars of these vessels:

The Devastation and Thunderer are precisely alike in every respect, and when afloat will represent exactly the same amount of fighting powers and of speed. Their principal dimensions will be: Length, 285 ft; extreme breadth, 62½ ft; draught of water (mean), 26 ft; and burden in tons, 4,406. They will be clothed with 12 in. of rolled armor plating on a teak backing, built into a framing of immense strength, of 18 in. in thickness, and the whole backed up with an inner skin of iron plating 1½ in. thick.

In the Devastation the upper deck, when the ship is complete for sea, will be, as nearly as possible, 4 ft. 6 in. above the water, except at the bows, where a half sunk forecastle raises the height to a little over 9 ft. This height of the ship's bows will enable her to steam ahead to sea in rough weather, at the same time that it has been sufficiently kept down not to interfere with the fire of the guns of the forward turret over and round the bows of the ship. Although her free-board is as low as 56 in. above the water, her turret guns will be carried at a height of 13 ft., a height greater than that of any broadside armed iron-clad afloat.

There is no doubt that the Devastation will fight her guns at sea in such weather as would prevent the best of our broadside iron-clads opening their main deck ports, low as the former's upper deck is in the water. The explanation of this is, low as is the new ship's free-board by means of the armored breastwork which incloses the turrets and funnel, the virtual free-board for about one-half the length of the ship is raised fron 4½ ft. to 21 ft. At a considerable height above the breastwork deck there will be a hurricane or flying deck, from which the ship will be conned in heavy weather at sea, and to which access will be given by water-tight hatchways leading from openings in the breastwork deck. When the ship is in action all these openings will be closed by armor covers, and the ship will be worked from "conning hoods" formed of armor plates built up within the breastwork.

The turrets of the Devastation are mounted on Captain Cole's system, working on a series of rollers fixed at the circumference of the base of the turret, and centred on a central cylindrical spindle; but their base rests upon the upper deck within the breastwork, and does not pass through the upper deck, as is the case with the Royal Sovereign, Monarch, Captain, and other turret ships. On the turrets the armor plating will be 14 in. in thickness round the gun-ports, and 12 in. in all other parts, on an iron frame and teak backing of 15 in. and 17 in., with an inner skin iron plating of 1½ in. The diameter of the turrets will exceed 31 ft.

The offensive powers of the Devastation and her consort will consist of two 30-ton guns in each turret, and her capabilities as a ram. As regards the guns, they are intended to be of the pattern at present adopted in the navy—the Woolwich improved Armstrong—and will throw 600-pounder shot of the ogival-headed Palliser type. For her propelling power she depends solely on her engines, which will consist of a pair of the combined nominal power of 800 horse. The engines will drive a pair of twin screws, each working independently of the other. The estimated mean speed of the ship will be 12½ knots per hour under a full pressure of steam, and the stowage for coals reaches the exceptionally large amount of 1,600 tons. This latter, it is estimated, will enable the ship to proceed to the Mediterranean and return without calling between the times of her leaving Spithead and anchoring there again at the conclusion of her voyage; or, it would enable her to cross the Atlantic, fight an action, and afterwards return to a home port without having to renew her stock of fuel.

Each engine works independently of the other, and drives its own screw; so that under these conditions both engines must become disabled simultaneously to deprive the ship of her steam power. One engine, or one screw, may be rendered unserviceable for a time, but the other will remain available for the propulsion of the ship.

The complement of officers and men for the new ship will be 250 all told, a small number compared with the size of the ship, but quite sufficient for every purpose on board a ship where there is no work aloft. The comfort and health of all on board are well provided for.—*Engineering.*

BREECH-LOADERS.—The following list of the various breech-loading systems which have been adopted by the armies of the European States appears in the "Eastern Budget":—England—For the conversion of old rifles, the Snider; for new rifles, the Martini-Henry. France—For the conversion of some old percussion muskets, the Snider; for the new rifles, the Chassepot; a metal cartridge is now being made for the latter weapon, the old paper cartridge not being considered satisfactory. Russia—The Kruka for conversions, the 50,000 rifles already converted according to the Karte system having proved failures; Russia has also ordered 30,000 Berdan rifles from America, some of which have already arrived. Sweden and Denmark—The Remington, with Austrian barrels. Norway—Not settled. Italy—Pettiti; similar to the Chassepot (for conversions only). Switzerland—For conversions, the Millbank-Amsler; for new rifles, the Vetterli; Switzerland also possesses 10,000 Peabody rifles. Turkey—The Snider, for conversions. Belgium—The Albini. Spain—The Remington. North-German Bund—The needle gun. Bavaria—For conversions, the Lindner-Podelwils; for new rifles, the Werder. Holland—The Snider, for conversions. Montenegro has obtained 2,000 Kruka rifles from Russia. Austria—For conversions, the Wanzl; for new rifles the Wernal. Papal States—The Chassepot. Roumania—The Peabody.

ENGINEERING STRUCTURES.

ARCHED ROOFS.—We know not why, but the fact is not the less indisputable, that even to an uneducated eye the presence of a flat surface is abhorrent. Apart from any climatic influence, the exhilarating effect of a clear sky, exhibiting the entire grand dome of the Great Architect decorated with fleecy clouds, like the soaring monochromatic frescoes of a Sanzio or a Polydoro, is unconsciously responded to by all. On the other hand, when the vault is obscured by a thick flat curtain of lowering clouds, we share ourselves in

the depression of the heavens. It is as if one were transplanted from the centre of the stalls of a theatre to the back row of the pit, where the sagging floor of the balcony overhead debases the audience to the level of so many living Atlantes and Caryatides. From the operation of the same laws, we are quite confident that, sooner or later, the arch and the dome must have played an eminently important part in the science of decorative architecture; even in the absence of the wonderful mechanical properties of those structures by which a few cart-loads of worthless rubble are empowered to perform more useful work than the most colossal monolith ever quarried.

There is good reason to believe that arches existed in the pre-historic period. In its pointed form the arch was introduced in the pyramids of Gizeh and Meroe, and in the walls of ancient Etruria; to reappear, after the reign of the Roman semicircular arch, in the church of the Holy Sepulchre at Jerusalem, in the aqueducts of Constantinople. The analogous but more complicated structure—the dome—was almost coeval with the arch; brick vaults have been dug out in Nineveh; and the Church of St. Sophia, with its dome of earthenware and pumice stone 115 ft. in diameter, is a magnificent example of the powers of conception and the constructive abilities of the artificers of the sixth century. The brick Duomo of Florence and the shaped stone dome of St. Peter's, each about 140 ft. diameter, evidenced clearly that the architects of the fifteenth century were well up to their work, and that they considered a part of the latter to consist in the gratification of the natural instinct of the eye by the exhibition of arched and domed forms.

It is only now that engineers are beginning to recognize the immutability of the laws which render gracefully curved outlines so soothing to the eye. True, some of the noblest examples of arched viaducts are due to modern engineering; but we fear that we are indebted for these to the virtues of the arch as a carrying agent, rather than to any desire on the part of the engineer to gratify legitimately our organs of sensuous perception. We are borne out in this conclusion by the notorious fact, that when appearance is considered to be the first desideratum we have inflicted upon us straight soffitted, tinsel monstrosities, such as the Ludgate-hill Bridge of the London, Chatham, and Dover Railway, the contemplation of which is productive of a nausea which would be almost unendurable, were it not that an antidote is close at hand in the stately majesty of that giant in repose, London Bridge. If engineers had really reverenced the arch *per se*, apart from consideration of £ s. d., we should not so long have had little else than iron cobwebs for our station roofs, and it would not have been reserved to Mr. Fowler to illustrate the unchangeable nature of the laws of harmony, by the consistent adoption of gracefully outlined elliptical roofs for the covering of the Metropolitan Railway Stations. Such roofs differ as widely from the ordinary ridge and furrow type, as a Parisian umbrella differs from a flat-topped Chinese sunshade; the advance is simply from a state of barbarism to one of civilization.

On the Metropolitan Railway, with elliptical tunnels or bridges on either side of the stations, nothing less than elliptical roofs would completely satisfy the requirements of the eye. It would have been useless to attempt to effect a compromise with that organ by cambering the tie rods of the roofs or by any other similar makeshift. The same dodges have been tried over and over again in the Middle Ages; the tie beams were cambered, the hammer beams inclined towards each other, and in many instances, as at Outwell Church in Norfolk, curved braces were framed between those two members; in short, everything tending to assimilate the straight lined roof to the arch has been tried, and with a success proportioned to the degree of approximation to the perfect form.

The difficulties under which mediæval architects labored have no existence in this age of iron for engineers. If our forefathers wished to support their roof covering upon more durable roof ribs than the (four and a half centuries old) timber arches of Westminster Hall, or the still more ancient ones of Newstead Court, they could only resort to stone. To that material, consequently, they often did resort, and the stone principals, or gablets, 40 ft. span, still intact at the ruins of Mayford, and to engineers, by association, the still more interesting ones spanning the refectory at Conway Castle, afford pretty conclusive evidence that had these ancient masons been in a position to contract for the roofs of the Metropolitan Railway Stations, we should still have enjoyed our elliptical roof ribs, and their appearance would have been rather enhanced than detracted from by their execution in stone instead of in iron.

We fear, in this practical age, the delicate lines and curves of the Parthenon, or Temple of Theseus, designed to satisfy eyes that could not even endure a row of perfectly vertical columns—*fere nullam esse columnam quæ ad perpendiculum esse possit*—would not be appreciated; but we are at least justified in asserting that the most uneducated eye is qualified by nature to appreciate arched forms. We hope sincerely, therefore, that no more hideous square iron troughs, serving, but not expressing, the purpose of a bridge, and no more barn roofs done in iron, will be perpetrated in our metropolis, to serve as lasting memorials of the debased style of engineering architecture in this much vaunted Victorian age.—*Engineering.*

THE FOUNDATIONS OF LONDON BRIDGE.—In a recent report upon the communication between the north and south sides of the river Thames, Mr. Henry Carr furnishes the following interesting information upon the foundations of London Bridge, and their reliability: "The bridge is founded on piles driven 20 ft. into the clay, two tiers of sills at right angles to each other rest upon the piles, the sills are planked over, and upon the planking the masonry is placed. The space between the piles and sills underneath the planking is filled with brick-work and masonry. The weight of one of the middle piers and half of two arches, that is, the weight resting upon the foundation of one pier is 21,151 tons, which gives a load of 88 tons to be carried by each pile, and by the sills resting upon the pile heads. From experiments recently made at Mr. Kirkaldy's Testing Works, Southwark, it was found that a structure exactly similar to the timber foundations of the pier of London Bridge, so far from being able to carry 88 tons, yielded most seriously under 30 tons upon each pile.

"It is perfectly clear, therefore, that the pile and timber foundation is not equal to the work put upon it, and the sills are no doubt either crushed, or the piles are driven down; the weight of the bridge must therefore rest upon the ground of the

intermediate spaces between the piles, and the structure may be considered as resting on the clay, but with the bed disturbed and broken up; in fact, damaged by the pile driving. The weight per superficial foot, supposing the total equally distributed over the whole area, would be 6 tons and a trifle over.

"This is not more than is placed on some of the railway bridge piers (or rather columns doing the work of piers) across the Thames, but these railway columns have certainly as much to do as can safely be put upon them.

"From this examination it is evident that, although London Bridge stands well at present, it would not be desirable to put on additional weight, even if the additional weight were so small as probably to produce no appreciable effect; nevertheless, should additional weight be put on, and any settlement take place at any future time, the Committee might regret having increased the load upon a foundation which certainly has no strength to spare.

"There is one singular circumstance connected with London Bridge which probably may never have been brought under the notice of the Committee. The courses of the piers at low water incline towards the east. The eastern cutwater being in two cases as much as 10 in. below the western, this drop eastward is corrected to some extent in the superstructure, it being about 7 in. in the parapets. There are various reports as to the cause of this drop east; the letter from Mr. Morris, which is appended to the memorandum, gives an explanation which the Committee may perhaps think worth putting on record. The letter was written in reply to an inquiry as to whether the drop in the courses arose from a settlement of the foundations, or from what other cause.

"*Letter from Mr. Morris to Mr. Carr.*

"'DENMARK-HILL, *April* 15, 1869.

"'MY DEAR SIR,—I am very pleased in being able to give you the information you require.

"'There never was any settlement of the piers of London Bridge. I made the drawings of that bridge for Sir John Rennie. Messrs. Jolliffe and Banks were the contractors; their principal master of the works was Mr. Henfrey, who was a very competent person. He had a young man with him, Mr. Hollingsworth, a relative. The foundations were constructed in cofferdams, and the pumps fixed at the down stream end, the piles driven, and the platforms were laid with an inclination towards the pumps. The stone was dressed in courses at the Isle of Dogs, brought up and laid with that inclination, Mr. Henfrey intending to change the incline courses into horizontal long before they approached low-water mark; but he died, and young Hollingsworth took the initiative, and did not discover the error before it reached the springing. He, no doubt, gained what he could afterwards.

"'I am, my dear Sir,

"'Yours very faithfully,

"'E. W. MORRIS.'"

—*Engineering.*

MAKING FOUNDATIONS IN MARSHES.—A new process of making foundations for bridges in marshy soils has been recently used on a branch line of the Charentes Railway Company, in France. This line crosses a peat valley to the junction of two small rivers; the thickness of peat was so great that any attempt to reach the solid ground would have been very expensive. In order to obtain cheaply a good support for the bridge, two large masses of ballast, accurately rammed, were made on each bank of the river, and a third one on the peninsular between the two. The slopes of these heaps were pitched with dry stones, for preventing the sand from being washed away by the rain or by the floods in the river. Over the ballast a timber platform is laid; this platform carries the girders of the bridge, which has two spans of about 60 ft. each. When some sinking down takes place, the girders are easily kept to the proper level by packing the ballast under the timber platform; this packing is made by the plate-layers with their ordinary tools. This simple and cheap process has succeeded quite well. The same difficulty was overcome by a different plan on an ordinary road near Algiers. This road crosses a peaty plain, nearly one mile broad; the floods and elasticity of the ground prevented the formation of an embankment. The road was to be carried over a viaduct across the valley, but the foundations of this viaduct presented serious difficulties, the thickness of peat or of compressible ground being nearly 80 ft. It was quite possible to reach the solid ground with cast-iron tubes sunk with compressed air, or with any other system; but neither the implements nor the suitable workmen were available in the colony, and it was a great expense to bring them, and especially the workmen, from France. The use of timber piling was, of course, out of the question, as timber is very expensive in Algiers, and quickly becomes rotten; but there was a set of boring implements which the men used to work it. The engineers began boring holes 10 in. diameter down to the solid ground. These holes, lined with thin plate-iron pipes, were afterwards filled with concrete up to the level of the ground. Each of these concrete columns bears a cast-iron column; these columns are properly braced together and support the girders of the viaduct, which is divided into spans of about 20 ft., and is 20 ft. high over the ground. This system has succeeded very well, and is to be extended to another large valley.—*Mechanics' Magazine.*

THE OUDH CANAL.—The Government of India has just issued orders approving the designs of Captain J. G. Forbes, R. E., for a canal project in Oudh and the adjoining districts, much larger than that of the Ganges canal. The river Sardah flows from Nepaul into Oudh through the malarious jungle caused by the drainage of the Himalayas. From that river, water is to be taken off sufficient to irrigate 19,000 sq. miles between the Sardah and the Gogra on one side and the Deoha and Ganges on the other. Colonel Anderson, the Inspector-General of Irrigation, states that the cutting of the first 12 miles will cost half a million sterling and will be of greater magnitude than any yet carried out in India. The "Times" gives the following particulars of this undertaking: "The dam is to be made at Bumbassa, the canal head at Nuglah, 8 miles lower. A supply of 13,000 cubic ft. a second is required, and if the Sardah cannot give this at Bumbassa and Maggaen, lower down, the Korreallie river will help. The main canal will run through Oudh for 80 miles, and then bifurcate into the Benares canal, 280 miles long, and the Jounpore canal, 235 miles. But the project embraces the western districts also. The whole is estimated to cost close on five millions sterling,

and a return of 11 per cent. is estimated, after paying 4 per cent. charges. This is to be got, however, only by enforcing the severe provisions of Colonel Strachey's Bill, or charging the proprietors of irrigable but not actually irrigated lands 5½d. per acre. As so much of the canal will pass through Oudh, which has an abundant water supply from wells and marshes, Colonel Anderson takes a much less sanguine view of its prospects, nor does he expect the Oudh Talookdars or their tenants to take the water unless exceptionally low rates are imposed. The surveys for the proposed canal from Ragmahal to Calcutta are going on, and that land is being taken up for the canal from the Damooda at Raneegunge to Serampore or Howrah, on the south side of the Ganges and Hooghly. The line of canal in Sirhind, too, running chiefly through the Native States of Putiala and Nabha, is being surveyed. The cutting down of the expenditure on ordinary public works by so much as 1½ million sterling a year will set engineers free for State railways and canals."—*Mechanics' Magazine.*

M. Boutet's plans for the construction of a bridge across the Channel are just now attracting great attention in France, and he is now engaged on a working model a hundred metres long, which will serve at once as a model of the bridge to be thrown across the Rance, at St. Malo, and of a part of the projected bridge across the Channel. By the direction of the Emperor, the model is to be erected on the Champs de Mars or in the Bois de Boulogne, and engineers from all coutries will be invited to inspect it. The same inventor is constructing a portable foot bridge of one span of a hundred metres, divided into 10 sections, which can be put together and thrown across a river in less than 5 minutes. This is intended for the use of the army, and is destined to supersede the present pontoon system. If the large working model we mention stands the trials it will be subjected to, an entire revolution in the construction of iron bridges and viaducts will be the result. M. Boutet's system, it should be said, involves the use of $\frac{1}{10}$ of the iron employed in bridges constructed on the usual plan.—*Railway News.*

Wrought-Iron Chimneys.—A new wrought-iron chimney has been recently erected at the Creusot Works. It is 197 ft. high, and 6 ft. 7 in. in diameter. At the bottom the diameter is increased to 10 ft. by a curved base, which is fastened by vertical bolts to masonry work. The thickness of the sheet-iron is $\frac{5}{16}$ in. at the top, and $\frac{7}{16}$ in. at the bottom. There is an inside iron ladder. The weight of this chimney is 40 tons; it has been riveted horizontally, and lifted afterwards with a crane. Another one, 275 ft. high, will soon be erected, but by a different system; it will be riveted vertically, with an inside scaffolding. These chimneys are built for an extension of the Creusot Works, especially intended for steel making. There will be eight Bessemer converters, where the cast-iron will be run direct from the blast-furnace; there will be also many Martin's furnaces, and an extensive workshop for melting steel in crucibles, where it will be possible to melt together 50 tons of steel.—*Engineering.*

A New Breakwater.—Mr. W. Jackson, of Windsor street, Brighton, has invented an original arrangement in the construction of breakwaters. This consists of a sort of honeycomb formed by fastening together in parallel lines a large number of cast-iron tubes; the structure is so placed that the waves flow through the pipes, that is to say, the axes of the pipes are parallel to the direction of the most dangerous winds or currents. Mr. Jackson has recently submitted to the War Office a scheme for the erection of a small breakwater according to his system, in Seaford Bay. He is not the first inventor of metallic breakwaters; Capt. Vetch, R. N., invented, some years ago, a system of iron caissons, which he proposed for the Plymouth Breakwater; and in 1857 Lieut. Manico, R. N., patented an apparatus which he called also a caisson, though it would be more accurately defined as a crate, which he proposed to fill with stones, so as to form submarine blocks. Mr. Jackson's breakwater is widely different, however, from Capt. Vetch's and Lieut. Manico's inventions. The latter are proposed to be used in the body of a pier or sea defence; the former, according to the inventor's ideas, should be placed at some distance outside. We have had no opportunity of seeing the tubular breakwater tested, though the inventor says he has erected one at Odessa, and that it has answered very well.—*The Engineer.*

NEW BOOKS.

A Treatise on the Richards Steam-Engine Indicator, with directions for its use. By Charles T. Porter. Revised, with notes and large additions, as developed by American practice. With an Appendix containing useful formulas and rules for Engineers. By F. W. Bacon, M. E., Member of the American Society of Civil Engineers. New York, D. Van Nostrand, 1869.

We welcome this book from the hands of practical men. It supplies a want that has long been felt by working engineers. No one can claim to be an accomplished engineer, without a knowledge of the Indicator and its uses.

Now that we have an improved instrument that can be applied to any steam engine, from the slow-moving marine to the swift locomotive, the Indicator is becoming an indispensable appliance, and is coming rapidly into use.

The original work, by Mr. Porter, published by Elliott Brothers, London, is a valuable work; but the American engineer requires examples from motors with whose working he is more familiar.

The American editor has retained the general description of the instrument, the sample diagrams, and the analysis of the original work. To this he has added diagrams from the most approved American marine, stationary, and locomotive engines, prepared from the originals, taken by himself.

It is believed that the locomotive diagrams are the only ones ever obtained in this country from an express engine while making a regular trip. The American engineer will feel gratified when he compares these "cards" with English diagrams, taken in a similar manner.

Mr. Bacon has added an appendix, containing useful tables and formulas.

The rules for proportioning belts to any required transmission of power, are exceedingly valuable.

The reputation of the American editor, among practical engineers, will insure an extensive demand for this little book.

A Practical Treatise on Concrete and How to Make It. By Henry Reid, C. E. London: E. and F. W. Spon.

Less than a year has elapsed since we had occasion to copy from the New York "Tribune" a notice of a work by the same writer, entitled "A Practical Treatise on the Manufacture of Portland Cement." In that notice special attention was called to the fact that a large portion of the work was nothing more nor less than a wholesale plagiarism from General Gillmore's standard American "Treatise on Limes, Hydraulic Cements and Mortars," for which no credit or acknowledgment whatever, nor the slightest reference to the source from which it was drawn, was made by the writer. Entire pages and subjects were appropriated bodily without alteration, not as extracts or quotations, but as new matter, and were given to the public as such.

In the present treatise on "Concrete," this literary theft and professional discourtesy is continued in the same wanton spirit which characterized its predecessor. The book contains five plates of drawings, one of which represents a well-known device for testing the strength of mortars. The other four are exact copies of plates in General Gillmore's work, taken by Mr. Reid for his own use and benefit, without any recognition of the ordinary and usual amenities of trade or professional intercourse. The readers of the Magazine will therefore readily infer that at least a portion of Mr. Reid's book possesses merit, and that he is, to some extent, a judicious and skilful gleaner in fields over which others have thoroughly worked before him.

This English publication is a mere compilation from well-known sources, and contains nothing that is new to the profession, while the bulk of it is of no practical use or application in this country.

The History and Progress of the Electric Telegraph, with descriptions of some of the apparatus. By Robert Sabine, C. E. Second Edition, with additions. New York, D. Van Nostrand, 1869.

This neat little book gives a detailed description of the various telegraphic systems at present employed, with many that have been superseded by recent improvements.

The numerous diagrams aid the reader to comprehend the more complicated systems.

Among the topics treated are Early Observations of Electrical Phenomena; Telegraphing by Frictional Electricity; Telegraphing by Voltaic Electricity; Telegraphing by Electro-Magnetism and Magneto Electricity; Telegraphs now in Use, including: The Needle; Morse Dial; Type Printing; Electro-Chemical and Copying Telegraphs; Overhead Lines; Submarine Lines; Underground Telegraphs, etc., etc.

Counterpoise Gun Carriages and Platforms. Published by direction of Brevet Major-General A. A. Humphreys, Brig. Gen. and Chief of Engineers, U. S. A. For the use of officers of the Corps of Engineers. By Capt. W. R. King, U. S. Corps of Engineers, Brevet Major, U. S. A. Washington, Government Printing Office.

Capt. King's report is published in a quarto volume of sixty pages of text and seventeen folding plates.

The author thus defines his subject: "The object of this class of inventions is to secure additional cover for barbette guns when "out of battery," and this is generally sought by allowing the gun to descend, either during or immediately after the recoil, to a lower position than that occupied when "in battery."

In order to prevent the too rapid descent, and to facilitate the raising of the gun after loading to its proper position for firing, a counterpoise of some kind is generally employed, and this latter, though not always used, may easily be shown to be essential to the proper working of the carriage, especially for the heavier calibre of guns. We may, therefore, in the absence of a better name, call them "*counterpoise gun carriages.*"

The report is confined to a classification and detailed description of the various methods comprehended in the above general definition. This work is exceedingly well done. For sale by Van Nostrand.

The Metals Used in Construction — Iron, Steel, Bessemer Metal, etc., etc. By Francis Herbert Joynson. Edinburgh, William P. Nimmo, 1868. For sale by Van Nostrand.

The chemical and physical properties of the various "irons" now in use are clearly set forth in this little work of Mr. Joynson's.

The smelting processes are briefly treated. The subsequent operations of puddling, toughening, converting cast into malleable iron, and steel making, make up the bulk of the book.

One chapter is devoted to annealing, case hardening, and tempering iron and steel.

The book presents a concise statement of the methods employed in producing the most useful of the metals, and is designed rather for the general reader than the scientific student.

How to Become a Successful Engineer, being Hints to Youths intending to adopt the profession. By Bernard Stuart, Engineer. Fourth Edition. Edinburgh, Wm. P. Nimmo. For sale by D. Van Nostrand.

In the absence of systematic technical education for engineers, such hints as this author affords are well timed.

The kind of study, and the proper routine of experiment, is clearly set forth for the especial benefit of those who are seeking both instruction and advice.

The student of engineering finds it extremely difficult to reconcile the advice he gets from professional instructors, with that which is given him by practical and successful men.

Our author endeavors to indicate what knowledge is of most worth to him who would become a successful engineer. It is already meeting with a large sale in this country.

The Mechanic's and Student's Guide in the designing and construction of General Machine Gearing, Eccentrics, Screws, Toothed Wheels, and the drawing of rectilineal and curved surfaces, with practical rules and details. By Francis Herbert Joynson. Edinburgh, Wm. P. Nimmo.

This work is designed especially for draughtsmen.

The text affords a course of instruction in progressive exercises of the eighteen folded plates, which form a part of the volume.

The typography and engravings are exceedingly well done.

RECORDS OF STEAM-BOILER EXPLOSIONS. By EDWARD BRINDON MARDON, Chief Engineer to the Midland Steam Boiler Inspection and Assurance Co. E. & F. H. Spon, London.

This book of about one hundred and fifty pages, is in four parts; the first being a paper on steam-boiler explosions, read before the meeting of the Institution of Mechanical Engineers, at Manchester, England. The remaining parts are respectively very brief records of explosions in 1866, 1867, and 1868.

The author concludes that "boiler explosions do not arise from mysterious causes, but generally from some defect which would have been remedied if it had been known to exist." The illustrations, 166 in number, are poorly executed, but are of great practical value from their undoubted correctness. For sale by Van Nostrand.

GUIDE PRATIQUE DE L'OUVRIER MÉCANICIEN. Par M. A. ORTOLAN. For sale by D. Van Nostrand.

An excellent work for the purposes indicated in the title. The book begins with short treatises on Arithmetic, Algebra, Practical Geometry, and Trigonometry. These, of course, are mere outlines, but contain whatever is necessary for the understanding of the body of the work, which deals with Practical Mechanics. The chapters on Transmissions des Mouvements and Machines Motrices Hydrauliques are especially good. A fine descriptive atlas accompanies the text.

COURS DE MÉCANIQUE THEORIQUE ET APPLIQUÉE. Par MM. FUSTUGUERAS ET HEEGOT. For sale by D. Van Nostrand.

This little work is one of a series intended for the use of practical men. Its treatment of subjects is very clear and complete, making but little use of mathematics. The illustrative engravings are very fine.

The subjects, in their order of treatment are: Moteurs en General; Moteurs Animés; Du Vent Comme Moteur; Mouvement des Fluides; Recepteurs Hydrauliques; Recepteurs à Axe Horizontal; Turbines; Travail dans Machines à Vapeur; Divers Organes des Machines à Vapeur; Systèmes des Machines à Vapeur; Machines à Air Chaud; Machines à Gaz.

THE EARTH'S CRUST: a Handy Outline of Geology. By DAVID PAGE, F. R. S. E. Fourth Edition. Edinburgh, Wm. P. Nimmo, 1868. For sale by Van Nostrand.

The title of this book explains its scope. The author is well known, and is one of the most successful among scientific writers, in popularizing technical science for general readers.

The book before us presents an outline of geology, such as any well-informed mind would like to possess, and is designed to stimulate the reader to the study of works of a fuller and more systematic character.

MODERN WORKSHOP PRACTICE, as applied to Marine and Locomotive Engines, Floating Docks, Dredging Machines, Bridges, Ship Building, Cranes, etc. By JOHN G. WINTON. Strahan & Co., London.

This is designed to form one of the famous Weale series. It is thoroughly practical, and will prove valuable not only to mechanical engineers, but to inventors who desire to attain a better familiarity with the technical terms and empirical formulas of the shop, than is afforded generally by the rudimentary works. For sale by Van Nostrand.

FREE-HAND DRAWING: A Guide to Ornamental, Figure, and Landscape Drawing. By AN ART STUDENT. Profusely Illustrated. Edinburgh, Wm. P. Nimmo. For sale by Van Nostrand.

The several chapters of this treatise give instruction in Relation of Materials; Free Hand Drawing of Lines; Shading; Application of the Principles to Elementary Subjects, and Sketching from Nature.

It is one of the Handy-Book series of the well-known Edinburgh publisher.

AN ESSAY ON A NEW SYSTEM OF FORTIFICATION. By GEORGE E. HEAD. A. M., Captain Twenty-ninth Infantry, and Brevet Major, U. S. Army. With Illustrations. New York, D. Van Nostrand, 1869.

This is a pamphlet in quarto form, containing twenty-four pages of well-printed matter, interspersed with a sufficient number of diagrams to explain thoroughly the author's system.

The invention involves the use of heavy guns, mounted in turrets; the latter to be capable of being worked vertically in excavations.

THE ELEMENTS OF BUILDING, CONSTRUCTION, AND ARCHITECTURAL DRAWING.—With one hundred and thirty-three illustrations, drawn on wood, by the author. By ELLIS A. DAVIDSON. Cassell, Peter, and Galpin, London and New York.

The object of the author of this book is to give a general knowledge of the principles of building construction, and at the same time to afford practice in architectural drawing. The book will be of service to students of practical science, who desire an easy introduction to the technicalities of building.

A PRACTICAL TREATISE ON MILL GEARING, WHEELS, SHAFTS, RIGGERS, etc., for the use of Engineers. By THOMAS BOX. London, E. & F. N. Spon. For sale by Van Nostrand.

Of several excellent works on this subject, this is the most compact, and it seems to us the most serviceable.

The author is favorably known among engineers, through his former works upon Hydraulics and Heat.

LONG AND SHORT SPAN RAILWAY BRIDGES. By JOHN A. ROEBLING. Published by D. Van Nostrand.

We call attention to the article on p. 78 of this number with reference to this book.

MISCELLANEOUS.

OPTICAL CORRECTION IN DESIGN.—Optics, or that branch of it which more particularly relates to the phenomena of unassisted vision, is a study architects and those interested in design generally would do well to investigate. Every architect at least knows that his elevations, sections, and other geometrical drawings do not correctly represent the actual structure as regards projection or proportion of parts, and that he has frequently recourse to perspective to aid him in arriving at

that due modification and effect of masses and grouping which distance, position, and other considerations would give to his design. Many, it is true, sadly overlook these considerations, especially the effect of distance and angle under which the actual building will most generally be viewed. How frequently, for example, do we find cornices cutting off from sight the parapets of buildings; chimney stacks placed so as to interfere with general outline, and ornamental and other accessories so located as to be lost altogether from view. Countless buildings and features of them have been marred, obstructed, or miserably mangled by disregard or ignorance of the principles of optical projection. It may be said a building cannot possibly be viewed from the same point at all times and under all circumstances. This is true; but there is generally some point or points of a structure more accessible than others to spectators or those located within its walls, and it is from these points of sight that I conceive a proposed building should be considered; its masses, grouping, and features studied on paper after the demands of arrangement and construction have been fulfilled.

Perspective itself is a practical application of the theory of optics, and a branch of art more neglected than it should be by architects, who often deem it a subsidiary method of representation, or who either wilfully or ignorantly misrepresent its principles; and this is the more inexcusable as it then becomes an art of falsifying, instead of truthfully rendering on paper, the design of the architect. It is a branch of study, indeed, whose thorough acquaintance an architect should pride himself in possessing, in addition to the other means of geometrical representation which every builder or mechanical workman can possess. I shall not here consider the principles of an art on which many treatises obtainable by all have been written; simply observing that its essence lies in its accuracy. Moreover, the position of the "horizontal line" or "point of sight" should never assume fictitious altitudes or positions, nor the "points of distance" be exaggeratedly extended or improperly limited, as is often done in competition drawings. The "picture plane" is also frequently assumed to be in false and impossible positions.

I shall here confine my readers' attention to some of the more important instances of the value of optical correction, or, more properly, that *compensation*, in design itself which perspective does not consider, but which critical experience has forced upon the attention. One of the most remarkable of the illusions of which a correct eye becomes cognizant is the *apparent* concavity or depression which perfectly straight lines or boundaries possess. The theory of this peculiar property seems, I think, to be that retention by the retina of the eye of those visual rays which proceed from definite points or limits of an object. The more striking points of the object by a "persistence or impression" are retained, the intermediate rays of pencils being comparatively lost to the sight. Thus, in limited or terminable straight lines, as a straight lintel, beam, or architrave, the extremities are immediately caught, and the persistence of impression of those points gives them a prominence upon the retina disproportionate to the other intermediate rays from the object. Irradiation is a phenomenon of optics very akin to this property, by which the impression made upon the retina extends beyond the size of the real image. The theory of binocular vision may be said partly to explain the above phenomenon; but I do not think, from experimental knowledge, that it can satisfactorily do so.

Vitruvius alludes to this peculiar defect of vision in his "Treatise on Architecture," which shows that this property was not unnoticed in the age of Augustus. He says: "If we do not endeavor to gratify the eye in its sense of beauty by proper proportions and *increase of size* when necessary, and thus remedy the defect of vision, a work will look clumsy and disagreeable." It is not only of the entasis or swelling of columns that Vitruvius speaks, but also of horizontal lines of buildings, as the line of the "stylobata" or upper step of the Greek temples. This, he says, should not be a straight line, but should be "very gently arched—highest in the centre, for if it be set out level, it will have the appearance of being sunk in the centre." The line of capitals, he further remarks, is to follow the inclination of the stylobata. The researches of the late Professor Cockerell, Mr. Penrose, Mr. Donaldson, Mr. Pennethorne, Jopling, Bell, and other mathematical critics, have gone to corroborate the passage of Vitruvius, and to prove beyond doubt that the parabolic, catenarian, or other curves, were employed by the ancient Greeks to compensate for the apparent deflection in the straight lines and surfaces of their structures. As we have noticed, this compensatory swelling or "entasis" is as much needed in horizontal members as cornices, beams, girders, and every feature which is "straight" or level, as it is necessary in the contour of our columns, shafts, and spires, though, as we shall see by and by, it is seldom applied to the latter purpose. Flat surfaces, also, as walls, are visibly subject to the same peculiar concavity as perfectly straight lines or boundaries. I will endeavor to show in the next and concluding paper, the application of the above compensation for this ocular deficiency.

Other delusive effects, explained on optical principles, such as the opposition of contrasting lines; the junction of curvilinear with straight; the relative proportioning of parts and features, demand attention in design. Æsthetically speaking, and every artist knows it, there is a good deal in easing abrupt junctions and harshnesses; in giving a slight convexity here and a gentle curve there; in harmonizing proportions and parts, before architectural designs can bear that stamp of æsthetic excellence and ideal refinement which should be the great aim of every educated architect.—*The Building News.*

BRITISH LIGHT-HOUSES.—We republish, from the "Pall Mall Gazette," the following particulars relating to the condition of the light-houses and floating beacons which protect the shores of the United Kingdom, and which were obtained from the last published parliamentary reports, and which point out the numerous glaring deficiencies in the existing system.

There were, in 1861, 212 lights on the English coast, of which 82 were shore lights under the Trinity House, 89 under local authorities, and 41 floating lights, of which 37 were managed by the Trinity House. In Scotland there were 46 light-houses under the Commissioners of Northern Lights, besides 67 fixed, and one floating light under local authorities, making a total of 114. The Ballast Board of Dublin managed 69 light-

houses and 4 floating lights, while only 4 fixed and 1 floating light were under local authority. A curious table is published comparing the number of British and French lights in proportion to the length of coast line. England has a light for every 14 miles of coast, Scotland one for every 39½ miles, Ireland one for every 34½ miles, while France exhibits one for every 12.3 miles. The light-houses in France are thus shown to be more than three times as numerous as in Scotland, compared with the amount of coast, and nearly three times as numerous as in Ireland. It ought, however, to be observed that the floating lights are not taken into account in this table. The lights of this description on the English coast, the value of which every mariner is ready to acknowledge, bring the English average up to 1 light for every 11.37 miles of coast, as compared with the French 12.3. The English lights have been steadily and gradually increasing in number, according to the advancing requirements of trade, during the last 150 years, while the French, which were very few until 1825, were, soon after that date, largely augmented by the erection of additional lights in the best positions, and in accordance with a well-considered and comprehensive plan. No other country of Europe, except France, is so well guarded as the United Kingdom.

The first-class lights, under the control of the Trinity House, are unsurpassed in brilliancy by any exhibited on foreign coasts. There are two principal means by which the stream of light from the lantern of a light-house is thrown in the required direction; one is by silvered parabolic reflectors, and is called the catoptric system; the other is by a series of concentric refracting lenses, which is known as the dioptric system. There are also, in some light-houses, combinations of the two systems, such, for instance, as those distinguished by the names of catadioptric and holophotal. The principle of refraction is generally adopted in Scotland, while reflectors have still a numerical preponderance in England and Ireland. This may, perhaps, be accounted for in some degree by the modern date of most Scotch light-houses as compared with those of the sister kingdom. While praise may generally be given to the mode in which the lights are maintained by the great corporations, the lights of the smaller local authorities are not so deserving of commendation — smoky lamps, candles, and tin reflectors, some of them even painted in front, may be found. The Royal Commissioners reported of Dover light that "the reflectors were incrusted with dirt, the glass of the lantern was covered with soot, which adhered to the fingers when the glass was touched on the inside. . . . It was evident that the lantern and reflector had not been cleaned for some time. . . . The place where the lanterns are lowered during the day was locked, the key lost, and it was necessary to break into it with a hammer. If the lamps which light the important port of Dover are inefficient, what is likely to be the case of 170 local authorities at small and unimportant harbors? At Aberystwith, on the 25th of October, 1859, the harbor-master went to bed without seeing that the pier and guide lights were put up. Before morning several wrecks had occurred, and many lives were lost.

In France the whole system is symmetrical. Lights are placed on a system—that their lights should cross. They are inspected on a system. The size of the flame, the quantity of oil to be consumed in an hour to produce a good light, and every minutest detail is calculated to a nicety. But no such supervision is now possible in the British Islands. If there were one central light-house board for the whole kingdom, with resident representatives for Scotland and Ireland, it would naturally be its business to carry out in minute details those plans which had proved most efficient.

In all foreign countries it seems to be assumed that light-house illuminations should be intrusted to persons selected for their fitness in these respects. Engineers, hydrographers, and professionally scientific men are always included in their board of administration. But in England no scientific element exists at all.

Surveying and Levelling in China.—A small volume of "Lectures upon Chinese Rural Economy," which appeared not long since in St. Petersburg, from the pen of a well-known Russian writer, long a resident in China, M. Skatchkoff, affords some curious particulars respecting the practice of surveying and levelling amongst the Celestials.

The unit of land measure in China, M. Skatchkoff tells us, is the *bû*, or fathom, which contains 5 Chinese ft. or *tse*. The Chinese foot, like the English, is supposed to have had its origin in the average length of that portion of the human frame whence it derives its name. Its value is about $1\frac{1}{4}$ English ft. The *bû*, or fathom, is consequently equal to $5\frac{4}{7}$ English ft. 240 sq. *bû* make a Chinese acre, or *mû*, which is equivalent to .16 of an English acre. This is the measure recognized in the assessment of the land-tax. It is distinguished, accordingly, as the "Government" or "Treasury" *mû*. There are two other varieties of acre occasionally employed—the "agricultural" containing 360 sq. *bû*, and the "great" *mû*, which is equal to 720 sq. *bû*. All these varieties have been in use from a very remote period. There is, however, reason to believe that, in ancient times, the "great" *mû* was most frequently employed—a fact which should be borne in mind in any investigation of the agricultural statistics given by early Chinese writers.

There is still another description of land measure—the *tsaen*—which includes a "treasury," an "agricultural," and a "great" *tsaen*, the latter being equivalent to $5\frac{3}{4}$ English acres, nearly.

The measurement of land is performed on the principle of chain-surveying. The chain is replaced by a line divided into fathoms and fifths (ft.), which is wound upon a reel fitted into an oblong wooden box. The latter contains, in addition, a supply of black paint for writing, and the small camel's-hair pencils or "stumps" which take the place of pens with Chinese scribes. 10 iron pins are used with the line, as by English surveyors.

As early as the fifth century of our era, it appears to have been customary for the governors of Chinese provinces to notice in their annual financial reports the changes in extent and assessable value of the cultivated lands within their jurisdiction. About the year 1000 A. D., however, a general survey was made of all the occupied lands in the empire, and a species of Doomsday-book was compiled for each province. This system has remained in force ever since. At the outset all the occupied lands were classed under one of the 5 following heads, viz., rocky or woody, hilly, champaign,

marsh, littoral. Three qualities of soil were recognized under each head—good, medium, and poor; and three descriptions of culture—good, middling, and indifferent. Subsequently, with a view to obviate the difficulties arising from the occurrence of several varieties of land within the same enclosure, it became customary to regard every separate plot of ground as divided into a number of equal parts, varying from 10 to 40 according to the character and value of the property, the quality and assessable worth of each sub-lot being registered separately if necessary.

M. Skatchkoff relates that during his sojourn in Djoungaria (Chinese Tartary), he was an eye witness of the labors of a survey commission, employed under the orders of the Pekin Government in setting-out certain new lands, distant about 30 versts from the town of Tchoutchoutchuk, in 250 *tsian* (six-penny) lots. The registration was performed by 2 Government clerks, under the superintendence of the commissioners. The field-work of the survey was executed in like manner, under the personal supervision of the commissioners, by 10 deputies chosen by lot from a list prepared beforehand of 350 applicants for the lands aforesaid. No outlay was incurred by the Government in these operations, as the expenses of the survey, which did not exceed 10 roubles, or 30 shillings in all, were charged prospectively against the future occupants of the allotments.

The canal system of the Chinese empire, and the universal application of irrigation, with its numerous ingenious adaptations, sufficiently testify to the practical skill of the inhabitants in hydraulic science. But the processes of levelling are conducted in a very primitive fashion.

The instrument employed is a modification of the water-level—an oblong trough of buckthorn or other similar wood, clamped with iron, and open at the ends. The interior surfaces of the sides are ruled horizontally with fine parallel lines in red or black paint, to serve as guide to the observer's eye. The trough is suspended by a single cord from a hook fastened beneath the apex of a wooden tripod stand. The usual height of the latter is 4½ ft. The instrument is adjusted by pouring water into the trough—which is deeper in the centre than at the extremities—and then shifting the suspending cord or the legs of the tripod until the surface of the water coincides with a pair of the horizontal lines. With this level and with the measuring-line and pins before described, all the requisite "field work" is readily and effectually, if not very expeditiously, performed.

All matters connected with the water-supply are intrusted to a guild with an unpronounceable name, the members of which receive special instruction in subjects appertaining to hydraulics.

M. Skatchkoff adds that geographical manuals exist of each district, which, besides a great variety of statistical information, contain the most minute details of its topographical, and especially of its hydrographical features. Many of these works are issued by the Government at very low prices, and revised editions appear from time to time.—*Engineer.*

THE HYDROSTATIC TEST.—The application of hydrostatic pressure to steam boilers, with a view to determining their fitness for use under steam, is so universal a practice with builders and inspectors, that to question its utility and propriety, is to inspire doubts as to the thoroughness of one's engineering education, and invoke severe criticism; and yet, it cannot be denied that much damage results from the system as practised. It is usual to delegate the duty of "testing," to persons totally unacquainted with the strength of iron or the damaging effect of sudden increments of pressure upon sheets already heavily strained; or, at least, they are not selected because of any particular fitness; and, in consequence, injudicious strains are placed on boilers, and the tensile strength of the iron seriously impaired thereby. We have frequently been told by steam users when discussing the relative merits of various systems of inspection, that they feel perfectly secure, because their boilers were built under special contract, and were subjected by the maker to 200 lbs. cold pressure, meaning to have us infer, that after such usage, they must surely not fail under 100 lbs. of steam; but we have made it our business to probe these parties further, and discover that seams were strained, braces broken, bolts sheared off, or insufficiently stayed surfaces distorted. These are the apparent results,—that which they don't see is the most injurious, and cannot be remedied as are the others.

They remind us, too, that the ultimate tensile strength of good iron is 50,000 to 60,000 lbs., forgetting that all the material used in construction,—indeed most of it will not bear more than half that amount, and further, that experience demonstrates the necessity of recognizing but about one-sixth of this figure available in constant use.

Let these persons, so confident of the ability of their boilers to withstand such severe and frequent tests, estimate the accumulated pressure of 100 lbs. per sq. in., or, a single inch of the boiler's length, measured, we mean, in the direction of its axis, and stand aghast at the tremendous force constantly struggling to free itself from its iron prison; or, will they prefer to listen to the result of an experiment, made during the past summer, at the Fort Pitt Iron Works, Pittsburg, Penn., with a cylindrical boiler, constructed of steel plates ¼ in. in thickness, by that establishment, for the Government, with a view to testing its adaptability to such use, relatively with iron. The trial was made in presence of the proprietors of the works, the Government engineer officer—under whose supervision it was built—the eminent constructing and mechanical engineer, Thatcher Perkins, and others. Measurement of the "girt" of the boiler was made—with a steel tape—before and during the process of pumping in cold water, and, when the pressure reached 780 lbs., a permanent enlargement of 3¾ in. was found to exist, in the direction of the circumference of the boiler, —*though no leaks were visible*,—and at 820 lbs., rupture occurred. It were well here, not to overlook the influence of the successive strokes of the pump, acting as a "water ram" on the pregnant boiler.

There is no doubt that boilers are very often severely and permanently injured, by the hydrostatic pressures to which they are subjected, in order to prove that they are strongly built. Each successive test weakens them, until they fail to respond to the requirement to longer bear the burden, and rupture, as did one recently at Mobile, while under the manipulation by this intelligent process of the United States Government *Inspector.*

But there is another feature. So popular has this method become, that implicit confidence is placed in it by many, who frankly deny that any

further test of a boiler's capacity for sustaining steam pressure is necessary. Not a month since we were informed by a deputy State Inspector—who, by the way, was an executive, and controlled subordinate deputies, that he *had* and could again *pass* boilers without having seen them. So expert had he become, that he cared simply to see the gauge (affixed to the pump in an adjoining apartment), and to note that it held the maximum pressure for 2 minutes. This was sufficient. What to him were blistered and burned plates, incrusted surfaces, corroded sheets, slack or broken braces, unskilful workmanship or faulty design? The iron had once more submitted to the demand of its annual inquisitor, regretting that he was not likely to be in charge when the exaustion oi its waning strength culminated in disaster.

We have recently been solicited to write on a boiler, whose fire sheet is so badly burned and blistered as to be positively dangerous; the firm is constantly changing engineers in their endeavor to get one who will stolidly risk his life and reputation, and the lives and property of others, without entering his protest; and upon what do the owners base their presumptuous, perhaps criminal conduct, in refusing to make needed repairs? Upon the certificate of the State Inspector that their "boiler has withstood a hydrostatic pressure of 135 lbs., and is safe to carry 90 lbs. of steam." For how long is this already dangerous condition to continue? For 12 months.—Ten yet to elapse! May we not reasonably look for some damage in this direction, ere long?—and when it does occur, at whose door shall the censure be laid? We shall pursue this subject further in our April number. —*The Locomotive.*

THE PHYSICAL COMMOTIONS THROUGHOUT THE GLOBE.—These commotions still continue; but the crisis would appear to have passed, if the diminished force of the various manifestations is to be trusted. There have, however, been recent earthquakes in Germany, as well as in Italy and France, and in Russia and India,, as well as in Australia, and South and North America,—in short, over all the globe. Professor J. Phillips, of Oxford, in his recent book on Vesuvius, gives it as his opinion, which accords with our own previously expressed idea, that the earth is now passing through one of its periods of volcanic activity. How long that period may last, no one can say. Of late the theory has been advanced that earthquakes are caused by the influence of the sun and moon on the internal waves of the molten sphere. A Mr. Rudolf Falb has lately written in defence of this hypothesis. Our own, as our readers know, is that there is a continued pressure of rotation upon the crust, from the molten mass of the interior, which molten mass we still believe in, with many geologists, notwithstanding recent opinions to the contrary. This pressure from within has crises, during which its centrifugal tendency to expansion rends the crust, and so relieves itself, while the rents are healed, as it were, by intruding molten matter, which solidifies and re-cements the crust. The rendings are greatest in the more equatorial regions, and just because it is there that the centrifugal power of the rotation is greatest; but by reaction of the pressure, earthquakes and volcanic belchings from the interior occur even in such circumpolar regions as Iceland, and in intermediate districts such as Italy.

It was the opinion of Mr. Hopkins, of Cambridge, or rather his demonstrated conclusion fron elaborate geological and mathematical investigations, that the power which has produced all the great rendings of the earth's crust must have been a power operative upwards from within; and this conclusion supports our idea that they arise from the rotary pressure of the molten and more mobile interior upon the less mobile or less yielding crust of the sphere. If the power of the rotation tends to increase with the known diminution of the obliquity of the ecliptic, the circumference of the sphere must be expanding; or, in fact, the molten and incrusted sphere must be growing in dimensions; and how far this may go on, or what may be its limits in the course of ages, it may be hard to say. We have already spoken of the instructive light which the state of the other planets, as to coincident rapidity of rotation, size, and levity, sheds on this question.

The tidal wave predicted by Leut. Saxby, as a consequence of the co-ordinate position of both sun and moon, did not occur with us to the anticipated extent, at the time predicted; but there have been tides since 3 ft. higher than the dreaded one, and which have done much damage on the banks of the Thames from not being looked for. The Americans say that the tidal wave on their shores rolled in as high as 18 ft. at Newcastle, New Hampshire, where it ran 125 ft. beyond high-water mark; and elsewhere, as at the Bay of Fundy, there has been an enormous tide, with destructive floodings.

If the angle of the ecliptic was ever of *much* greater extent than it is, the most tremendous tidal waves of later ages must have been as nothing to what probably once occurred, when the world may have "stood out of the water and in the water, so that the world that then was, being overflowed with water, perished," as St. Peter so mysteriously tells us, in regard to the Scriptural deluge.—*The Builder.*

PREVENTING BOILER INCRUSTATION.—Every steam user who has been troubled with scale in his boilers—and very few have not—has doubtless tried to effect its cure by means of one or other of the various boiler compositions before the public. Some may have succeeded; some, to our knowledge, certainly have not. This may have been owing to various circumstances; amongst others, that of using the proffered remedy without ascertaining its chemical fitness for the water in which it was to be used. It has been too much the custom to assume that a given boiler composition will prove perfectly effectual in every kind of water. This mistake has only been found out after fruitless efforts to remedy the evil, but which, by a discriminate selection, might have been cured. Steam users, however, who have hitherto been unsuccessful in preventing scale, will be glad to learn that a very perfect remedy is now being brought before the public by Mr. Smith, of 204 High Holborn, London. This preparation is a powder composed of several ingredients which are very certain in their action in preventing scale and perfectly harmless in their effect upon the metal plates. It is now more than a year since Mr. Smith first brought out this preparation. During that time it has been used by a number of firms whose testimony to its merits we have seen. We select, from a number of testimonials, two from parties whose names are well known to our readers. The first is from Messrs. Merryweather and

Sons, the steam fire engine manufacturers, who, under date of January 21, 1869, write: "We have used your boiler composition in our steam boilers, and find it to surpass, in our estimation, all others that have hitherto been used by us. We find that half the stated quantity is quite sufficient to keep our boilers free from deposit."

The second testimonial, which is dated March 16, 1869, is from Mr. Field, the inventor of the boiler bearing his name, and is as follows: "I am tired of trying various preparations supposed to prevent incrustation in steam boilers. As regards your own composition, I have as yet only given it a partial trial in the case of a large Cornish boiler, in which the incrustation was very stony. I examined this boiler after six weeks' use of your preparation, and found that the greater part of the incrustation had been dissolved or reduced to a state of powder. On washing some of the plates, the iron is plainly visible, and I am of opinion that the whole of the scale will be removed in course of time. I have not seen so marked an action with any other composition, and am much pleased with it, especially as I have looked for action on the iron, and found none whatever." Another firm writes that "it does not injure the slides or brass fittings of the engine." Upon this latter point—the action of the preparation upon metal—we recently had a conversation with an eminent analytical chemist. This gentleman assured us that, after some months of varied and searching experiment, he could not detect the slightest signs of injurious action upon any of the metals which he had subjected to its influence under the most trying conditions. These highly favorable results, together with those no less favorable which are vouched for in practical working, lead us to predict that Mr. Smith's composition will come into general use, and will prove of the highest value to steam users.—*Mechanics' Magazine.*

CLEANING WATER RESERVOIRS.—There is no class of works which requires more careful attention during their progress than those relating to the supply, service, and storage of water. They are specially intended to deal with a most treacherous element, and should there be a weak point in any part of them, it will most undoubtedly be discovered before they have been many months in use. The large reservoirs necessary for the storage of the water supply of a town, are the most prominent items of those engineering enterprises termed water works. As might be anticipated, they must not only be kept in thorough repair, but they require occasional cleansing to maintain their contents sweet and wholesome. As there are generally two or three separate reservoirs in the same locality, the easiest plan of effecting their cleansing and the removal of any foul deposit that may have settled along the bottom is to run them dry by turns, and accomplish it by manual labor. It is nevertheless not difficult to understand that an instance might arise where it would not be possible to run the reservoir dry. There might, in fact, be only one reservoir, or the company might have so little storage space to spare, that it could not afford to employ this plan. Lastly, the supply of water might be so scant as to forbid, on that score, the adoption of the method. This very difficulty of being unable to run off the water, and so expose the bed of the reservoir, has been encountered at Lyons, and so successfully contended against that a short account of the means adopted will be both interesting and instructive.

By virtue of their agreement, the company in question were obliged to supply to the town a quantity of water amounting per diem to 900,000 gallons. This quantity had to be filtered before passing into the basins or reservoirs leading into the pipes supplying the town—a process which demanded a large extent of superficial space. As this supply was drawn from the Rhine, the level of that river very materially affected the rate of delivery into the reservoir, and recently, in consequence of the low state of the river, it was necessary to build a new tunnel nearly a quarter of a mile in length, to obtain a sufficient quantity of water. For some time past the engineers of the company remarked that the infiltration process did not proceed with its usual activity, and that the level of the river being constant, and also the surface of infiltration, the quantity of water arriving in the reservoirs was seriously diminished. Upon making an examination into the cause of this diminution, it was ascertained that the gravel at the bottom was overlaid with a thick white deposit of a marly-looking substance, bearing a strong resemblance, as far as appearance went, to white vitriol. This deposit came from the masonry of the reservoirs, which was all set in cement and hydraulic lime, and after attaining a certain thickness, opposed a very considerable resistance to the passage of the water. The problem to solve was, the removal of the deposit without disturbing the superincumbent liquid, or interfering with the constant supply, and the following means were adopted: A couple of pumps were set in operation by a portable engine. At the extremity of the tubes of these pumps was fixed a small apparatus, measuring about four square feet, which was open, and allowed to penetrate to the depth of a few inches in the gravel. The depth of the penetration was regulated, so that no very large quantity of water should be drawn up by the pump, but only sufficient to assist the removal of the deposit, and a little of the finest sand which came with it. The deposit separated itself from the gravel, and was removed without leaving any trace of the operation or disturbing the purity of the water.—*Building News.*

THERE has been much difference of opinion among engineers as to whether the pressure in a steam boiler was greatest at the top or bottom. Many have contended that the pressure was several pounds less at the bottom, although no good reason could be given for this theory, while others have maintained that the pressure was greater at the bottom, from the fact that the weight of water must be added to the indicated pressure of steam. We had the pleasure of seeing this question definitely settled a few days since at the Print Works of Messrs John and James Hunter, Hestonville, Penn. An elbow was put on the end of the blow-off pipe which entered the mud-drum. Into this elbow a plug was screwed, which was tapped to receive a half-inch pipe; to this pipe a steam gauge was attached and the blow-off cock opened. On comparing the gauges attached at the top of the boiler, and to the mud-drum as described above, it was found that the pressure was greatest at the bottom by some pound and a half, thus proving the latter theory, that the pressure at the bottom is, the indicated pressure plus the weight of the column of water.—*Locomotive.*

SIPHON DISCHARGE.—Mr. E. T. D. Myers, C. E., of Richmond, in a letter referring to the article from the "Journal of the Franklin Institute," published in our November number, detailing the difficulties in the use of a large siphon, says:

"It has come in the way of your correspondent to avail himself of a similar appliance, on two occasions.

"In the first instance the lift was about 20 ft. and the length 125 ft.; in the second, 10 ft. lift and 350 ft. long.

"4 in. pipes, with ordinary bell and spigot joints, caulked with lead, were used for both siphons. The inlet and outlet were provided with stop-cocks, such as are used upon street mains. There were two ordinary brass stop-cocks, tapped into the pipe at the summit. Both were opened while filling the pipe with water. There was no air chamber, but the lower end of the siphon was turned up thus:

the discharge taking the form of a low jet, and forming a 'trap' for the external air.

"I think that the omission of this trapped outlet will always lead to the trouble experienced at the Blue Ridge; yet I am not aware that it has been adopted save in the above mentioned cases.

"A word as to the lead joints. Unless the main be subjected to great variations of temperature, they may be relied on under pressures far exceeding those encountered in the siphon. The writer has himself tested the joints of 12 in. pipes, in the hydraulic press, up to 360 sq. in. lbs., and has found a longitudinal strain of 20 tons insufficient to tear such pipes asunder at the joints.

"Let any one form a girder of three such pipes united at the joints by lead, well caulked, and he will be surprised at its stiffness.

"The discharge of the Blue Ridge siphon is stated at 43¼ gallons per minute. This is in close accordance with the formula given by Prof. Rankine. 'Civil Engineering,' p. 685, which give 42¾ gallons.

"M. Darcy's formula (vide Fontaines publiques de Dijon) for old and rusted pipes, translated from metrical measures into ours, will be as follows:

$$V = 40.20 \sqrt{\frac{D\,H}{L}},$$

in which all dimensions are in feet and V= feet per second. The result with this formula would be still less, viz., 40 gallons.

VAN NOSTRAND'S ECLECTIC ENGINEERING MAGAZINE for December, closes the first year of that valuable work. The promises of the publishers have been more than kept, and we have reason to know that their anticipations of success have been fully realized. It is, emphatically, "an abstract and brief chronicle" of whatever is useful in the science of engineering, and of what is going on in the field of current operations. A glance at the table of contents of the volume (published with this No.) is in a sense a summary of these vast complex sciences and interests, and enables one to realize the outlay of labor and discrimination which such a publication demands. The table is, in a word, a lexicon of more than 400 different topics, many of which have been treated under from two or three to fifty sub-heads. To take a few examples alphabetically:—Bessemer steel and process is treated in 16 different articles, under as many heads: Blast Furnaces, 34; Boilers, 35; Bridges, 33; Cars, 38; Engineering Architecture, 16; Iron, 104; Ordnance, 51; Permanent Way, 22; Rails, 48; Railways, 177; Ships, 30; Steam-Engines, 29; Steel, 72; Tunnels, 16. It is announced that the size of the Magazine will be increased the coming year by the addition of 16 pages.—*Chicago Railway Review.*

PRESERVATION OF STONE BY THE USE OF THE BLACK OXIDE OF COPPER AND ITS SALTS.—Dr. Robert, in "Les Mondes," argues to prove that the decay of all natural building stones is effected by various causes, and that among these a very minute lichen, *Lepra antiquitatis*, is one of the worst enemies of the stone; and this to such an extent that, for instance, the beautiful marble sculptures of the well-known Parc de Versailles will, unless proper measures are taken for staying the process of decay, become unsightly and ugly masses of dirt, and quite irretrievably lost as works of art within another fifty years. He instances such buildings at Paris as the Bourbon Palace, the Palais du Corps Legislatif, the Mazarin Palace (l'Institut), the Mint, and others, and points out that dust, spiders' webs, and the action of rain combine, with the minute lichen above alluded to, to call forth the decay of stone, especially of such parts, first, where any sculpture or ornamental carving promotes the deposition of dirt and dust. He argues by examples which every one can see, and which, moreover, are important, in consequence of the length of time which has elapsed since the protective action of the black oxide and salts of copper commenced, that the action of the two last-named substances is preservative to stone. In reference to granite, he states, adducing Waterloo Bridge as an example, that this stone is also, according to the experience of Egyptian engineers, far more readily affected by a moist climate than one would be led to believe. The obelisk of Luxor, brought from Upper Egypt to Paris, has become blanched and full of small cracks during the forty years it has stood on the Place de la Concorde, while forty centuries had not perceptibly affected it as long as it was in Egypt. Granite, in a moist clime, becomes the seat of a microscopically small cryptogamic plant, which greatly aids destruction; and it is, moreover, a well-known fact that the disintegration of stone, consisting of three separate minerals (quartz, mica, and felspar), depends very greatly upon the thorough and intimate mixture, as well as upon the chemical composition of the same, each of these minerals, separately, being readily enough weathered.—*The Building News.*

THE revival of the Merchant Marine is engaging the earnest attention of the Chamber of Commerce and press of New York. The "N. Y. Times" holds that in order ever to get back to where we were in 1860, we need to get rid of our high tariffs; to help our shipbuilders by admitting the raw materials they need, free from duties; in due time to allow our merchants to buy ships where they can buy them cheapest; and especially to open new and irresistible conduits of commerce, like the Darien Canal, before counting on the control of Chinese or Asiatic commerce.—*Chicago Railway Review.*